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EVALUATION OF EXPLOSIVES STORAGE CRITERIA

COMPUTER PROGRAM USER'S MANUAL

By

James D. Donahue

Falcon Research and Development Company
Denver, Colorado

March 1970

Prepared for

Armed Services Explosive Safety Board
Washington, D. C.

Contract DAHC04-69-C-0095

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I. INTRODUCTION

The FORTRAN computer program described herein was developed for the Armed Services Explosive Safety Board in partial fulfillment of the requirements specified under contract DAHC04-69-C-0095. This study [1] was directed toward developing additional data for use in evaluating quantity-distance criteria for blast damage. Updated analytical and experimental evidence has provided a basis for storage distance requirements applicable to a number of specific civilian targets* not previously considered. It will be convenient to have a copy of Reference 1 available to use in connection with this manual.

Computer programmed analytical methodology has been formulated which will develop a minimum separation distance, for a selected target and quantity of explosive, which minimizes the probable risk that the blast damage resulting from an accidental detonation will exceed a predetermined acceptable level. These procedures were derived, where possible, through application of results from more recent analytical and experimental blast damage programs in which the structures or structural elements subjected to blast could be related through similar structural properties and construction techniques to the civilian targets of interest. This computer program was used to derive the results presented in Reference 1. In that reference, plots showing the computed separation distances are presented for a number of target parameter variations, and the defined damage level in each target when exposed to blast from five charge sizes. These data may be compared with present quantity distance standards, which are shown on each

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*The term "target" is used throughout this report to refer to personnel and to public structures which normally require protection from accidental detonation of stored explosives. Such targets include civilian personnel, various types of private dwellings and buildings, mobile houses, commercial aircraft, automotive vehicles, other storage magazines, etc.

plot for the convenience of the reader. Plots of the incident pressure and impulse values associated with these distances have also been prepared for each target type. These latter plots are clearly of the hyperbolic form which has been predicted by earlier workers in the field [2].

II. SELECTED TARGETS AND DAMAGE LEVEL SPECIFICATIONS

Ten representative or generic types of civilian targets and variations thereof may be analyzed with the existing computer model. These are:

1. Modern split-level house constructed of a combination of masonry and frame.
2. A modern church with laminated beams and an A-frame roof.
3. A modern elementary school.
4. A multi-story office building.
5. A passenger bus moving around a curve on a highway.
6. A camper-pickup unit.
7. A stationary mobile home.
8. Personnel.
9. The front wall of a standard storage igloo.
10. A commercial jet aircraft.

Specific examples of these targets have been described in precise detail [1] so that the functional relationship between their actual component weight, elasticity, strength, dimensions, etc., and the dynamic response to blast might be determined. Modifications of these targets may be treated by changing the suggested input data parameter variations (such as Young's modulus, modulus of rupture, etc., for specific target components) or the fixed parameter specifications within the program itself (such as the angle of inclination of the house roof, etc.).

Because separation distance is usually an expensive requirement, the acceptance of some minor or incipient structural damage to the targets is necessary in order to minimize these costs. Thus, specific degrees of acceptable damage have been sought for each target which minimize the risk of serious injury to occupants without requiring separation distances that are excessive.

In establishing "acceptable damage" criteria for each of the above targets, a number of unacceptable degrees of damage

were first considered for each structure. The explosive storage separation distance for a given explosive quantity was then established with relationship to a "worst case" or first damage level. For the stationary targets (home, church, school, office building, and the mobile home), two levels of unacceptable damage or risk levels were considered. The first was damage which constituted a critical hazard to occupants from high velocity glass fragments from broken windows. The second was blast damage sufficient to cause an immediate hazard to occupants of the building as a result of collapse of the roof or walls of the structure. In the analysis of these structures, levels of pressure-impulse--for each selected explosive quantity--which cause each of these types of damage were established. The greatest separation distance at which unacceptable damage occurs denotes the critical damage, and, thus, is designated as the "worst case".

Acceptable damage to each structure is identified as all structural damage of a degree up to <u>but not including</u> the specified critical damage. For example, if a house roof is predicted to fail before the brick or frame walls--and also before flying glass becomes a significant hazard--then the acceptable level would include all damage up to, but not including, roof collapse. In this case, a distance corresponding to the blast forces required to crack the roof rafters, but not sufficient to structurally collapse the roof, is identified as the recommended separation distance.

The defined acceptable damage levels for all targets are discussed in the individual treatment of each target in Section IV.

A separate model of blast response has been developed for each structural component of each target which can reasonably be expected to suffer damage within the range of charge sizes and scaled distances, λ_D, considered ($4 \leq \lambda_D \leq 100$). Thus, for example, the house is analyzed in terms of the behavior of its frame roof, frame walls, and masonry walls. The first failure of any of the three components (to the established maximum acceptable damage level) defines a minimum distance requirement for the entire target.

The dynamic interaction models consider both the elastic and plastic deformation involved in target response and several of these models rely heavily on the concept of requiring a

critical impulse to be imparted to the target member in no more than one fourth of its fundamental resonant period [5]. Where the blast forces act against both front and back surfaces of a target or component, both forces have been considered. The models rely upon the work of the Ballistic Research Laboratories for descriptions of the blast wave phenomena in terms of peak incident pressure, incident impulse, and positive duration [3]. These values, together with appropriate reflection factors and target dimensions, have been used to define the reflected pressure and impulse to which a particular target element must respond as a function of time.

This computer program provides output data relative to the critical periods of each component, associated critical impulse, required separation distance to meet the maximum acceptable damage criterion, and the blast exposure of the other target components. The program will accept a series of structural properties as inputs to the program so that the effects of variations in tensile strength, elasticity, mass, etc., can be shown for each target element.

While the models and computer program elements are extensively concerned with target structural properties, it will be valuable to remember that reasonable protection of occupants, rather than the protection of structure, forms the basis for this program.

III. COMPUTER PROGRAM ORGANIZATION

A. SUBROUTINES

The computer program has been formulated as a series of linked subroutines in order that it might also be used on smaller storage capacity computers. A card input is utilized. Flow charts and a listing are presented in Section VI. All input data pertaining to blast parameters and target component parameter variations are read in as an initial step by the HEADR subroutine (see flow charts - blocks 1 through 17). Thereafter, a single control card and the CALLR subroutine direct the program to the desired target analysis subroutines. Each target is evaluated separately with the exception of the office building. In its treatment, separate subroutines are used to analyze the half wall with windows and the solid arching type block wall with no openings.

The appropriate subroutines and applicable blocks of the flow charts for each target analysis are shown in Table I.

As linked subroutines are used, separate sets of monitor control cards, Common and Dimension Statements, and output format cards are provided in each subroutine (see source deck listing, Section VI). Only one set is necessary, of course, if the program is modified to one continuous program. Some duplication in the numbering of output format statements has also been used; this must be avoided if modification to one continuous program is made.

B. INPUT DATA

In order to facilitate the discussions of the analysis of each target, the required computer input data cards are outlined in Table II.

TABLE I. Subroutine Identification and Applicable Flow Chart Sections

Subroutine Number	Subroutine Name	Flow Chart Block Numbers
1	Input Data - HEADR	1-17
2	Control Program - CALLR	18-24
3	HOUSE ANALYSIS - HOUSE	25-120
4	CHURCH ANALYSIS - CHRCH	121-182
5	SCHOOL ANALYSIS - SCHOL	183-253
6	OFFICE HALF WALL ANALYSIS - OHAFW	254-296
7	OFFICE FULL WALL ANALYSIS - OFULL	297-337
8	BUS ANALYSIS - BUS	338-381
9	CAMPER-PICKUP ANALYSIS - CAMPR	382-425
10	MOBILE HOME ANALYSIS - TRLER	426-466
11	STORAGE IGLOO ANALYSIS - DOOR	467-498
12	PERSONNEL ANALYSIS - MAN	499-529
13	AIRCRAFT ANALYSIS - AIRC	530-558

TABLE II. Computed Input Data

Card No.	Description and Format
1	Charge Sizes - (FORMAT 5F12.2): Five charge sizes must be specified. No limitation on charge size is made; however, only scaled distances $4 \leq \lambda_D \leq 100$ are considered. Therefore, only distances applicable to this range are considered. In Reference 1 charge sizes of 1,000, 10,000, 100,000, 1 million, and 9 million pounds were used. (Array Name - CS(I),I=1,5)
2-11	Peak Incident Overpressures - (FORMAT 5F12.2): Ten cards are used to input the incident overpressures corresponding to scaled distances $4 \leq \lambda_D \leq 40;(1)$ and $45 \leq \lambda_D \leq 100;(5)$*. These values may be determined from Reference 3 or 10. (Array Name - PO(I),I=1,50)
12-21	Scaled Positive Durations - (FORMAT 5F12.2): Ten cards are used to input scaled positive durations corresponding to the scaled distances $4 \leq \lambda_D \leq 40;(1)$ and $45 \leq \lambda_D \leq 100;(5)$. These scaled durations are of course multiplied by $\sqrt[3]{\text{charge size}}$ to obtain the actual positive duration for use in the program. Scaled durations in the above range may be obtained from Reference 1 or 3. (Array Name - TAU(I),I=1,50)
22-31	Reflected Peak Overpressures for Non-Normal Surfaces - (FORMAT 512.2): Ten cards are used to indicate the reflected peak overpressures for surfaces with approximately a 70-degree slope (as measured from the vertical). These values are used in the house roof and aircraft fuselage analyses. They again are given for scaled distances in the ranges $4 \leq \lambda_D \leq 40;(1)$ and $45 \leq \lambda_D \leq 100;(5)$. These values may be obtained from Reference 1. (Array Name - CPR(I),I=1,50)

*This notation should be interpreted as the consideration of all integer values of λ_D in the range of $4 \leq \lambda_D \leq 40$ and all integer values in increments of 5 in the range $45 \leq \lambda_D \leq 100$.

TABLE II (Continued)

Card No.	Description and Format
32	Young's Modulus of the House Rafter - (FORMAT 412.2): Up to 4 values of E may be specified. For Douglas fir lumber, values in the range of 1.1 to 1.5 million psi are generally applicable [4]. The number of variables specified here must correspond to the number used on cards 33 and 34. (Array Name - HRE(I),I=1,4)
33	Weight of 16-Inch Roof Section Per Lineal Foot of Rafter - (FORMAT 4F12.2): Four values of the estimated weight (per foot of rafter) of each 16-inch wide section of roof may be specified. For the composition roof considered in Reference 1, values from 10.4 to 11.3 lbs/ft were used. (Array Name - HRW(I),I=1,4)
34	Modulus of Rupture of House Rafter - (FORMAT 4F12.2): Up to 4 parameter variations of the modulus of rupture may be specified. Reference 4 indicates that for Douglas fir, the range of 8,500 to 12,000 psi is generally applicable. (Array Name - HRS(I),I=1,4)
35	Young's Modulus of House Frame Member - (FORMAT 4F21.2): Four estimates of the Young's modulus for the 2- by 4-inch stud may be indicated. These values correspond to those of the roof rafter. The number indicated must agree with the number used on cards 36 and 37. (Array Name - HFE(I),I=1,4).
36	Weight of 16-inch Frame Section per Lineal Foot of Wall - (FORMAT 4F12.2): Up to 4 estimates may be made. Values in the range of 18.3 to 20.0 lbs/ft are applicable. (Array Name - HFW(I),I=1,4)
37	Modulus of Rupture of House Frame Member (FORMAT 4F12.2): Up to 4 values are used. Values used for the house rafter are appropriate. (Array Name - HFS(I),I=1,4)

TABLE II (Continued)

Card No.	Description and Format
38	Young's Modulus for House Brick Wall - (FORMAT 4F12.2): Up to 4 estimates may be specified. A range of 1 to 1.3 million psi is considered generally applicable for 8-inch thick brick walls. The number of values used here must correspond to the number used on card 39. (Array Name - HBE(I),I=1,4)
39	Tensile Strength of the Brick Mortar - (FORMAT 4F12.2): Up to 4 values are specified. Values from 30 to 70 psi are appropriate. (Array Name - HBT(I),I=1,4)
40	Young's Modulus of the Church Roof Beam - (FORMAT 4F12.2): Up to 4 values may be specified for the laminated Douglas fir beams. The same range of values as indicated for the house rafter is considered to be applicable. The number of values used here must correspond to the number used on cards 41 and 42. (Array Name - CRE(I),I=1,4)
41	Weight of the 15-Foot Roof Section Per Lineal Foot of Church Beam - (FORMAT 4F12.2): Up to 4 parameter variations of the weight of each 15-foot wide section of church roof (including beam) are specified. Weights of 200 to 230 lbs/ft are appropriate for the church considered. (Array Name - CRW(I),I=1,4)
42	Modulus of Rupture of the Church Roof Beam - (FORMAT 4F12.2): Four estimates may be specified. The same range of values used for card 34 is appropriate. (Array Name - CRS(I),I=1,4)
43	Young's Modulus of the Church Roof Decking - (FORMAT 4F12.2): Up to 4 values are specified; the total number used must correspond with the number used on cards 44 and 45. For the church considered, values in the range of 1.3 to 1.55 million psi are applicable. (Array Name - CDE(I),I=1,4)

TABLE II (Continued)

Card No.	Description and Format
44	Weight of the Decking Member and Roofing Per Lineal Foot of Decking - (FORMAT 4F12.2): Up to 4 values may be specified. Values in the range of 13 to 14.5 lbs/ft are appropriate. (Array Name - CDW(I),I=1,4)
45	Modulus of Rupture of the Church Decking Member - (FORMAT 4F12.2): Up to 4 estimates are specified. The range of 1.1 to 1.4 million psi is applicable. (Array Name - CDS(I),I=1,4)
46	Young's Modulus of the School Stone Wall - (FORMAT 4F12.2): Up to 4 values are specified; the number treated, however, must agree to the number of variables used on card 47. Similar values as on card 38 are appropriate. (Array Name - SBWE(I),I=1,4)
47	Tensile Strength of the School Wall Mortar - (FORMAT 4F12.2): Four parameter variations are used. Similar values to card 39 are applicable. (Array Name - SBT(I),I=1,4)
48	Young's Modulus of the School Roof Beams - (FORMAT 4F12.2): Four estimates may be denoted--the member used must correspond to the number used on cards 49 and 50. Values from 1.3 to 1.55 million psi are appropriate for this school construction. (Array Name - SRE(I),I=1,4)
49	Weight of 2-Foot Wide Section of School Roof Per Lineal Foot of Beam - (FORMAT 4F12.2): Up to 4 values are specified. For this asphalt construction, the weight ranges between 30 and 40 lbs/ft. (Array Name - SRW(I),I=1,4)
50	Modulus of Rupture of School Roof Beam - (FORMAT 4F12.2): Up to 4 estimates are specified. Values in the range of 1.1 to 1.3 million psi are thought applicable. (Array Name - SRS(I), I=1,4)

TABLE II (Continued)

Card No.	Description and Format
51	Young's Modulus of the Office Hall Wall - (FORMAT 4F12.2): Up to 4 values are indicated, the number of which must agree with the number used in card 52. Values used on card 38 are appropriate. (Array Name - OHE(I),I=1,4)
52	Tensile Strength of the Half Wall Mortar - (FORMAT 4F12.2): Up to 4 values are specified. Similar values to card 39 may be used. (Array Name - OHT(I),I=1,4)
53	Young's Modulus of the Office Full Wall - (FORMAT 4F12.2): Up to 4 parameter variations are denoted. The number indicated must agree to that used on card 54. Values used for the half wall may be used. (Array Name - OFE(I),I=1,4)
54	Tensile Strength of the Office Full Wall Mortar - (FORMAT 4F12.2): Up to 4 values are used. Appropriate values lie in the range of 30 to 70 psi. (Array Name - OFT(I),I=1,4)
55	Bus Center of Gravity Location - (FORMAT 4F12.2): Up to 4 estimates are used; the number used on this and card number 56 must agree. These values indicate the height above the ground plane of the c.g. and probably lie in the range of 38 to 42 inches. (Array Name - BCG(I),I=1,4)
56	Bus Weight - (FORMAT 4F12.2): Up to 4 weights of the bus may be indicated. For this bus, 28,000 to 32,000 lbs is a reasonable approximation. (Array Name - BW(I),I=1,4)
57	Camper Center of Gravity Location - (FORMAT 4F12.2): Four estimates of the height of the c.g. above the ground plane may be indicated. The number used must agree with the number of parameter values used on cards 58, 59, and 60. These values lie in a range of 52 to 58 inches. (Array Name - CCG(I),I=1,4)

TABLE II (Continued)

Card No.	Description and Format
58	<u>Pickup Truck Center of Gravity Location</u> - (FORMAT 4F12.2): Four c.g. locations are indicated. Appropriate values are contained in the range of 30 to 34 inches above the ground plane. (Array name - CTG(I),I=1,4)
59	<u>Truck Weight</u> - (FORMAT 4F12.2): Up to 4 truck weights are specified. A range of 3,600 to 4,800 pounds is considered appropriate. (Array Name - TRW(I),I=1,4)
60	<u>Camper Weight</u> - (FORMAT 4F12.2): Four camper weights may be used. A range of 2,000 to 2,200 pounds is suggested. (Array Name - CPW(I),I=1,4)
61	<u>Mobile Home Center of Gravity Location</u> - (FORMAT 4F12.2): Up to 4 c.g. locations are considered. Appropriate heights above the ground plane lie in the range of 60 to 72 inches. The number used must agree with that used in card 62. (Array Name - TRGG(I),I=1,4)
62	<u>Mobile Home Weight</u> - (FORMAT 4F12.2): Four estimates may be specified. A range of 12,000 to 14,000 pounds was considered in Reference 1. (Array Name - TRWT(I),I=1,4)
63	<u>Modulus of Rupture of the Storage Igloo Steel Door</u> - (FORMAT 4F12.2): Up to 4 values may be used. Appropriate values are considered to lie in the range of 50 to 55 thousand psi. (Array Name - DORS(I),I=1,4)
64	<u>Weight of Man</u> - (FORMAT 4F12.2): Four weights of the personnel target may be entered. The total number of values should correspond to that used for card 65. (Array Name - WMAN(I),I=1,4)
65	<u>Presented Area of Man</u> - (FORMAT 4F12.2): Up to 4 presented areas may be used. The standing "average" man presents an area of 5.5 to 8.0 sq.

TABLE II (Continued)

Card No.	Description and Format
	ft. depending upon his orientation. (Array Name - PMAN(I),I=1,4)
66	Young's Modulus of Aircraft Frame Member - (FORMAT 4F12.2): Four values may be used. For the frame member considered values from 10.6 to 11.6 million psi are used. (Array Name - AIRE(I),I=1,4)
67	Dynamic Overpressure Factors for Aircraft - (FORMAT 5F12.2): Two cards are used to input these values. The ten values used must be .25, 1.25, 1.42, 1.54, 1.68, 1.72, 1.75, 1.78, 1.81. These numbers are used to indicate the relationship of static loading to dynamic loading in the aircraft analysis. (Array Name - AIRF(I),I=1,10)
68	Program Control Card - (FORMAT 12I2): The first two-digit, fixed-point entry on the card is denoted as NOT, the total number of target subroutines to process; the following 11 entries (IA(I)I=1,11) indicate the order of targets to be processed.

The control card is used to direct the flow of the program. The first entry, NOT, on this card indicates the total number of target subroutines to process. The order in which they are to be analyzed is denoted in the preceeding two-digit, fixed-point fields (denoted as IA(I)I=1,11). The order of targets is shown in block 24 of the flow charts. To illustrate, assume the three targets: the house, the school, and the man translation are desired to be analyzed. To achieve this programming, NOT is designated as 3, IA(1) is entered as 1, IA(2) is set equal to 3 and IA(3) is denoted as 9. No entry is made for IA(4) through IA(11).

It also must be noted that the computer program multiplies all Young's modulus (E) values by 10^6 and all modulus of rupture

(σ) values by 10^4 whenever used. This must be accounted for in the entry of the input data. To reflect the desired E values of 1 and 1.3 million psi for the house rafter, for example, it is necessary to enter 1.00 and 1.30 on card 32. Analogous adjustments must be made for all modulus of rupture values. All other values are entered with no modifications.

IV. ANALYSIS

A. SPLIT-LEVEL HOUSE

The selected representative type of residential home construction is illustrated in Figure 1. It is described in detail in Reference 1. In brief summary, the house roof is composed of 2- by 8-inch Douglas fir rafters on 16-inch centers. The rafters are 17 feet long and have a 5/12 slope. Each 16-inch section of composition roof (including rafters) supported by a rafter weighs approximately 10.4 to 13.3 pounds per lineal foot of rafter. The 7.5-foot high brick walls are of 8-inch solid brick construction; there is no reinforcing. The frame wall is 7.5 feet high containing a door and 2-foot 8-inch by 4-foot 6-inch windows. Two- by 4-inch studs on 16-inch centers support the 7.5-foot high frame wall. Each 16-inch section of fiberboard-plasterboard wall weighs approximately 18.3 to 20.0 pounds per lineal foot of stud.

Three exterior surfaces are considered as possible vulnerable components in the blast damage assessment model for this house: the roof, a portion of the brick wall containing no openings, and the frame section containing window and door openings. For all of the components, the risk level, or unacceptable damage, is defined as structural collapse. Therefore, damage levels which structurally degrade each component but do not cause their structural collapse have been defined. For the roof and frame wall sections, this damage is regarded as the cracking, but not complete severence, of one or more of the main 2- by 8-inch rafters or 2- by 4-inch wall support members. For the brick wall, a deflection of approximately 5 inches at its center is considered sufficient to seriously damage the wall through extensive cracking, but not to cause partial or complete collapse.

In the computer-programmed methodology, the minimum distance for each specific charge size which relates to the first-to-occur of the above three criteria, is determined. Then the required impulse and calculated impulse achieved at this specified distance is determined for all parameter variations considered for each of the other structural components, in order to insure that this truly is the minimum distance.

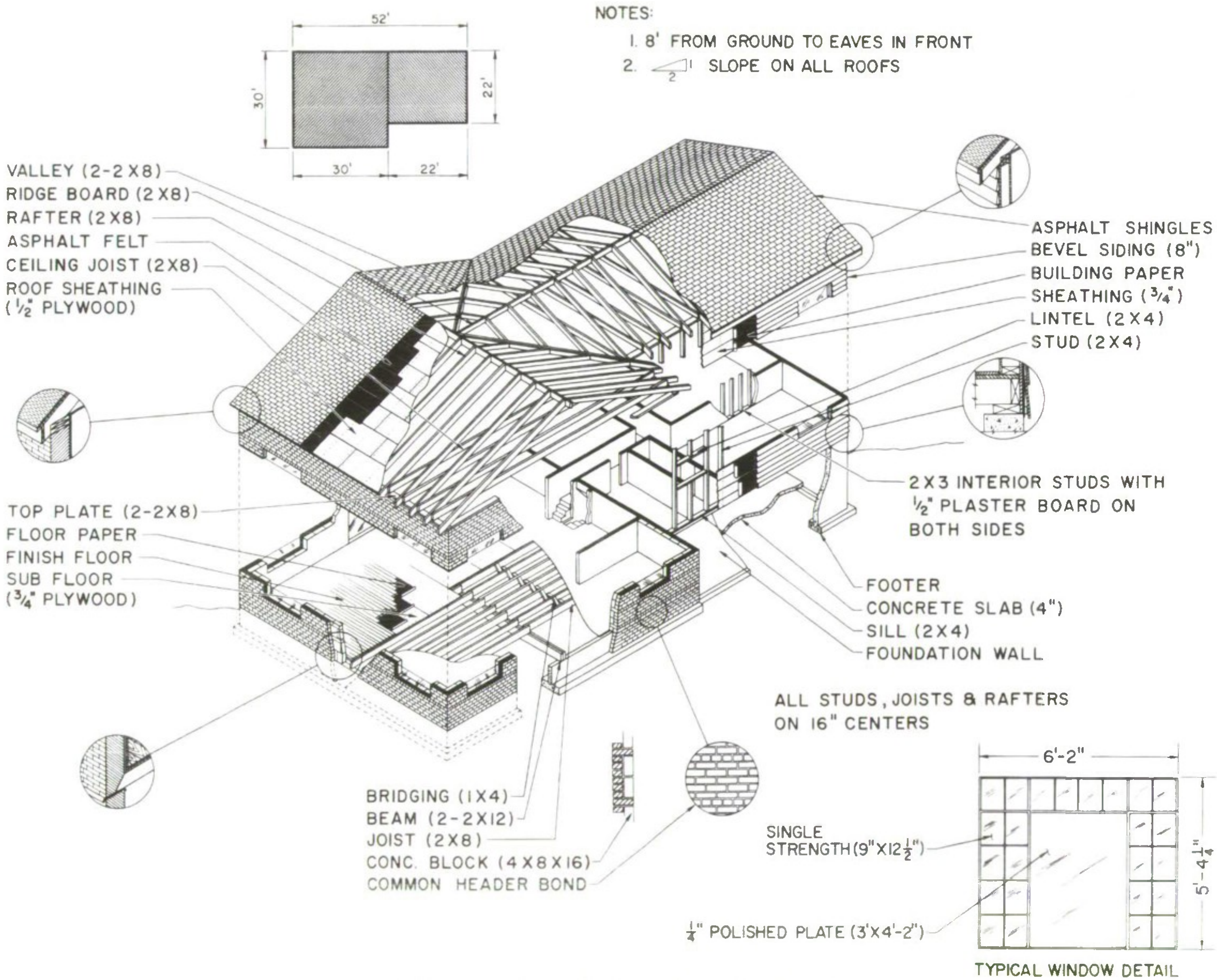


Figure 1. Split-Level House

The analysis of the wood portions of the house (roof and frame wall) and other targets is based on Sewell's concept of achieving a "critical impulse within a critical time period" [5]. His premise is that if a blast wave impinging upon a structural surface creates a velocity in the elements of the structure, relative to fixed points on the surface, greater than a "critical working velocity", then permanent deformation of the structure will result. A further assumption is that this critical velocity must occur within one-quarter period of the fundamental resonant frequency of the structure. Since critical working velocity is not known for many materials, Sewell advocates use of the critical impact velocity; i.e., that velocity causing tensile failure in the material. Because this criterion requires a minimum impulse in a fixed time period, it accounts for both the contribution of reflected pressure and impulse in that the delivery time limitation requires the reflected overpressure to be relatively high in order to produce the necessary impulse within the time limit. Additionally, the characteristics of the target are given consideration in that the critical time is a function of the resonant frequency of the target and the critical impulse is expressed as a function of target characteristics. These two considerations are considered necessary in accurately modeling target response-blast force interactions.

In the treatment of wood structures, the acceptable level of damage is based on simply cracking, but not completely breaking, a particular wood member. Therefore, the elastic phase of deflection, up to and including the yield point, is of primary interest. In the application of Sewell's criterion to wood structures, it is necessary that the critical impulse be imparted to the wood structure so that it will deflect beyond its yield point within one-quarter of its natural period.

1. Analysis of the Roof Rafter

A typical 17-foot long 2- by 8-inch roof rafter and the 16-inch wide section of roof it supports are analyzed as a simply supported, uniformly loaded beam. Its natural frequency is

$$p = \Pi^2 \cdot \left(\frac{EI}{m\ell^4}\right)^{1/2} \quad \text{radians/second} \qquad (1)$$

where:

E = Young's modulus (psi)

I = the area moment of inertia (in^4)

m = the mass per inch of beam (lbs)

ℓ = the length of the rafter (in).

Its critical period, C_p, becomes

$$C_p = \frac{1000}{4} \cdot \frac{2\Pi}{p} \text{ msec.} \tag{2}$$

The critical impulse, I_c, which must be delivered to the beam is that impulse which deflects the uniformly loaded beam beyond its point of maximum elastic deflection within C_p msec.

The calculation of the deflection of a loaded beam is based on the deflection of a loaded spring. The energy, U, stored in a deflected linear spring is

$$U = P \cdot \frac{\Delta}{2} \tag{3}$$

where P is the force required to cause the deflection Δ. In order to use equation (3), an expression for Δ must be obtained. If the load function, f(w), and sufficient boundry conditions are known, this can be obtained from a successive integration of

$$EI \frac{d^4\Delta}{dx^4} = f(w) \tag{4}$$

where:

Δ = deflection, and

x = distance along the beam.

In the analysis of the simply supported, uniformly loaded beam, the bending moment equation, M, is used in (4) and Δ obtained from

$$EI \frac{d^2\Delta}{dx^2} = -M \quad . \tag{5}$$

The equation thus obtained for Δ will involve a load, w. To find the maximum permissible value for w, w_o, a maximum tensile fiber stress, σ_{max}, is obtained and substituted in the equation

$$M_{max} = \frac{\sigma_{max} I}{C} \quad . \tag{6}$$

The M_{max} thus obtained is substituted for M in the bending moment equation along with an x that corresponds to the location along the beam of maximum moment. In the case of the uniformly loaded beam

$$M = \frac{\ell}{2} wx - \frac{wx^2}{2} \quad .$$

The maximum moment occurs when $x = \ell/2$, so that

$$\begin{aligned} M_{max} &= \frac{\ell}{2} w \frac{\ell}{2} - \frac{w}{2} \frac{\ell^2}{4} = \frac{w\ell^2}{8} \\ w_o &= \frac{8 M_{max}}{\ell^2} = \frac{8}{\ell^2} \cdot \frac{\sigma_{max} I}{C} \quad . \end{aligned} \tag{7}$$

The internal energy, U, is determined by integration of equation (4) over the length of the beam, where

$$p = w_o \, dx \quad . \tag{8}$$

In this case, the following simple expression is obtained

$$U = \frac{w_o^2 \ell^5}{240EI} \quad . \tag{9}$$

The necessary unit impulse, I_c, to provide this required energy is then computed from

$$I = \frac{1000 \cdot (2Um)^{1/2}}{(\text{area of the beam (in}^2))} \text{ , (psi-msec)} \tag{10}$$

The calculated critical period and critical impulse for the roof rafter depend upon the assumed strength and elastic properties of Douglas fir. The parameters E, w, and σ are known only within a range of values; thus, selected parameter values for these variables are entered as input data on cards 32, 33, and 34. A minimum separation distance for each selected charge size is then determined for each resultant set of calculated C_p and I_c.

Blast loading models presented in Reference 6 have been used in this computer program. Individual loading properties and the resultant imparted impulse on different surfaces of a target may be calculated, as well as net loading and impulse values. A detailed discussion of these models and the treatment of the non-horizontal roof of the house is given in Reference 1. The appropriate blast loading model is used in the computer program to determine a minimum separation distance for the house roof for each charge size and combination of selected parameter values. At each of these specified distances, similar estimates are made of the reflected impulse imparted to the house brick wall and frame portion. Comparative values are indicated following a brief discussion of the frame section and brick wall.

2. Analysis of the Frame Wall Section

The 2- by 4-inch wall support member is analyzed as a uniformly loaded, simply supported beam. Its dead weight is determined from its own weight and the 16-inch wide section of wall it supports. Calculation of its critical periods and impulses are made using equations (1) through (10).

Selected values of E, w, and σ are entered on input data cards 35, 36, and 37. A net blast loading concept is employed in which the net impulse is determined through integration of the overpressure function from time $t = 0$ to a time at which the overpressure function decreases to 0.2 psi.

It has been concluded from the results of several large-scale tests, that a steady pressure of approximately 0.5 psi over a time period equal to the wall calculated critical period is required for a simply supported 8-inch thick brick wall in order to cause tensile bond failure in the mortar.

In the computer model of the brick wall behavior, the calculation of the imparted reflected impulse is based on these assumptions. The blast loading model which reflects no opening in a perpendicular wall is used; it is thoroughly discussed in Reference 1. The required unit impulse is computed as the difference in the reflected impulse imparted to the outside of the frame wall within its one-quarter period, and that imparted to the rear surface. This concept is also detailed in Reference 1.

3. Analysis of the House Brick Wall

The derivation of the resistance functions, the work required to severely crack the wall, and the computed critical impulse necessary to do that work are discussed in Reference 1. From this study, it is concluded that when the overpressure decays to a low level, the latter part of the decay process is of little consequence to the effective impulse imparted to the wall. This point of minimum effective pressure is concluded to be in the range of 0.1 to 0.3 psi. In this computer model, the calculation of reflected impulse has been based on the integration from time $t = 0$ to a time at which the overpressure decays to 0.2 psi.

The calculation of reflected impulse required to severely crack the wall also depends upon the blast loading forces imparted to the roof which, of course, change with variations in separation distance. Thus, in the program output, a required unit impulse, based on the blast loading on the roof for each given charge and separation distance, is indicated for each set of parameter variations considered for the brick wall. Up to four values each of Young's modulus and the tensile strength of mortar are entered on input cards 38 and 39, respectively.

4. Sample Set of Computed Values

The computer output for the house analysis is arranged so that the computed critical periods and impulses are printed for the house roof, the frame section, and the brick wall section, in sequential order. Then, for each set of parameter variations for the house roof, the five charge sizes are considered in ordered to determine a minimum separation distance for each, with respect to the roof. As each of these values is

determined, the incident overpressure, peak reflected pressure and positive duration of the charge is noted, and a probabilistic statement concerning the likelihood of glass fragment injury to occupants, is made. The other two house components are then considered at this distance. The required, or critical, impulse and the reflected impulse achieved at this distance are printed for every set of values considered for these two components. Table III displays a typical printout for a set of representative parameters of the house roof and a charge size of 10,000 pounds.

Table III indicates that at the minimum separation distance of 289.9 feet for a 10,000-pound charge, the calculated reflected impulses on the frame portion and the brick wall of the house at this distance are far less than the necessary critical impulse values computed for the different sets of parameter variations considered.

B. CHURCH BUILDING

The A-frame church building is shown in Figure 2. The laminated Douglas fir wood beams are 7.6 by 16 inches by 39 feet long spaced on 15-foot centers. The upper 32 feet support the decking and roofing while the lower 7 feet support no loading. The 4-inch thick 8-inch wide double tongue and groove decking is considered to be simply supported on 15-foot centers. The decking is covered with asphalt roofing and has a combined weight of from 12 to 13.5 pounds per lineal foot of decking. Excluding the windows, the large (90 feet long) roof is considered the only vulnerable component of the church. The acceptable damage levels are considered to be the cracking of the laminated beams or cracking of the decking members. The minimum separation distance, therefore, is based on the first of these to occur.

1. Analysis of the Laminated Beams

The 39-foot laminated beam and the section of the roof it supports is analyzed as a step-wise uniformly loaded, simply supported beam with a dead load determined from its own weight and the weight of the 15-foot section of roof it supports (approximate weight, 200 to 230 lbs/ft of beam). Equations (1) through (10) are used by the computer program to

TABLE III. Computed Output for One Set of House Roof Parameters

MINIMUM DISTANCE FOR E = 1,300,000 psi; WEIGHT = 11.97 lbs/ft of roof; Mod of Rupture = 11,000 psi

CHARGE WEIGHT = 10,000 lbs; SEPARATION DISTANCE = 289.9 ft

INCIDENT OVERPRESSURE = 1.79 psi; PK. REF. OVERPRESSURE = 3.76 psi; DURATION = 39.4 msec

HOUSE FRAME SECTION:

Probability of Glass Fragment Injury:

For P_o = 1.79 psi, Probability of Serious Wounds = 0.

REQUIRED AND CALCULATED IMPULSES:

REQUIRED IMPULSE (psi-ms) =	34.86	CALCULATED IMPULSE (psi-ms) =	18.50
	38.34		18.50
	36.44		18.54
	40.09		18.54
	32.45		18.43
	35.70		18.43
	33.93		18.47
	37.32		18.47

House Brick Wall:

Required and Calculated Impulses:

Required Impulse (psi-ms) =	128.79	Calculated Impulse (psi-ms) =	43.44
	128.94		43.44
	128.76		43.44
	128.89		43.44

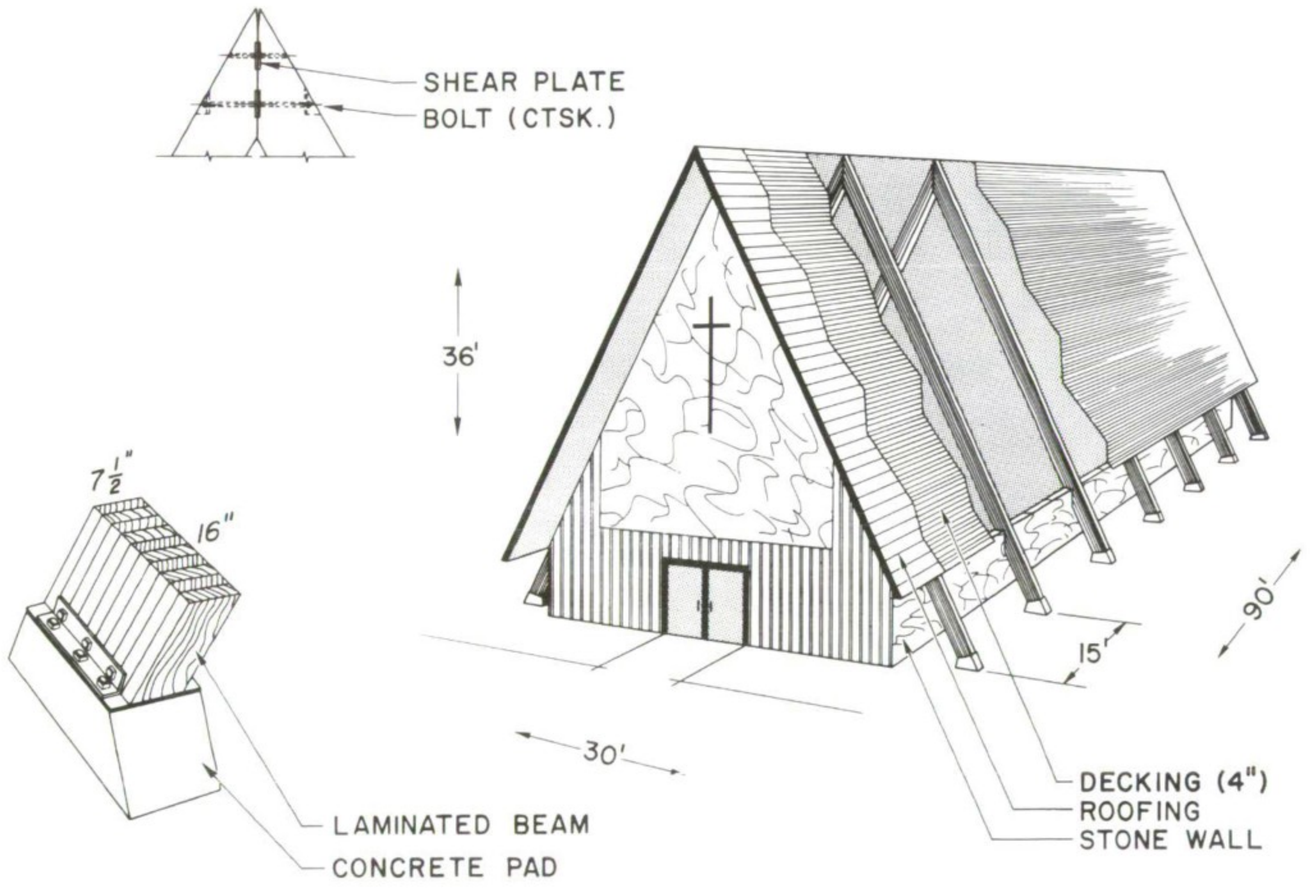


Figure 2. Typical Modern Church

determine the critical period and impulse. Up to four estimated values each of Young's modulus, the weight supported per foot of beam, and the modulus of rupture are entered on cards 40, 41, and 42.

The church roof has an angle of inclination of approximately 23 degrees from the vertical; the treatment of this non-normal surface in the calculation of the reflected impulse is given in Reference 1.

2. Analysis of the Church Decking

The decking members are also laminated Douglas fir and have similar strength properties as the other wood members considered. Up to four values of E, w, and σ may be entered on input cards 43, 44, and 45. The critical period and impulse calculations are made using equations (1) through (10). The blast loading model on a perpendicular surface with no back pressure on the interior side of the decking is used to calculate the impulse imparted to the decking within its critical period for each set of chosen parameter variations. This model is discussed in detail in Reference 1.

3. Comparative Results

In the previous analysis, the separation distance at which the church roof first fails for a 10,000-pound charge is 1,184.9 feet (for the set of parameters $E = 1.3 \times 10^6$ psi, $w = 215$ lbs/ft of beam and $\sigma_{max} = 11{,}000$ psi). The calculated impulse imparted to the decking at this distance is approximately 33 psi-msec. The average critical impulse required for the decking is about 110 psi-msec when comparative values of E, w, and σ are used. Thus, for this and all other charge sizes considered in Reference 1, the church roof beam was found to crack prior to the decking.

C. ELEMENTARY SCHOOL BUILDING

The roof of the elementary school (Figure 3) is supported on 3- by 14-inch by 28-foot long fir beams on 2-foot centers. The roofing is of built-up tar and gravel construction placed on 1-inch insulation board. A light tile ceiling is placed

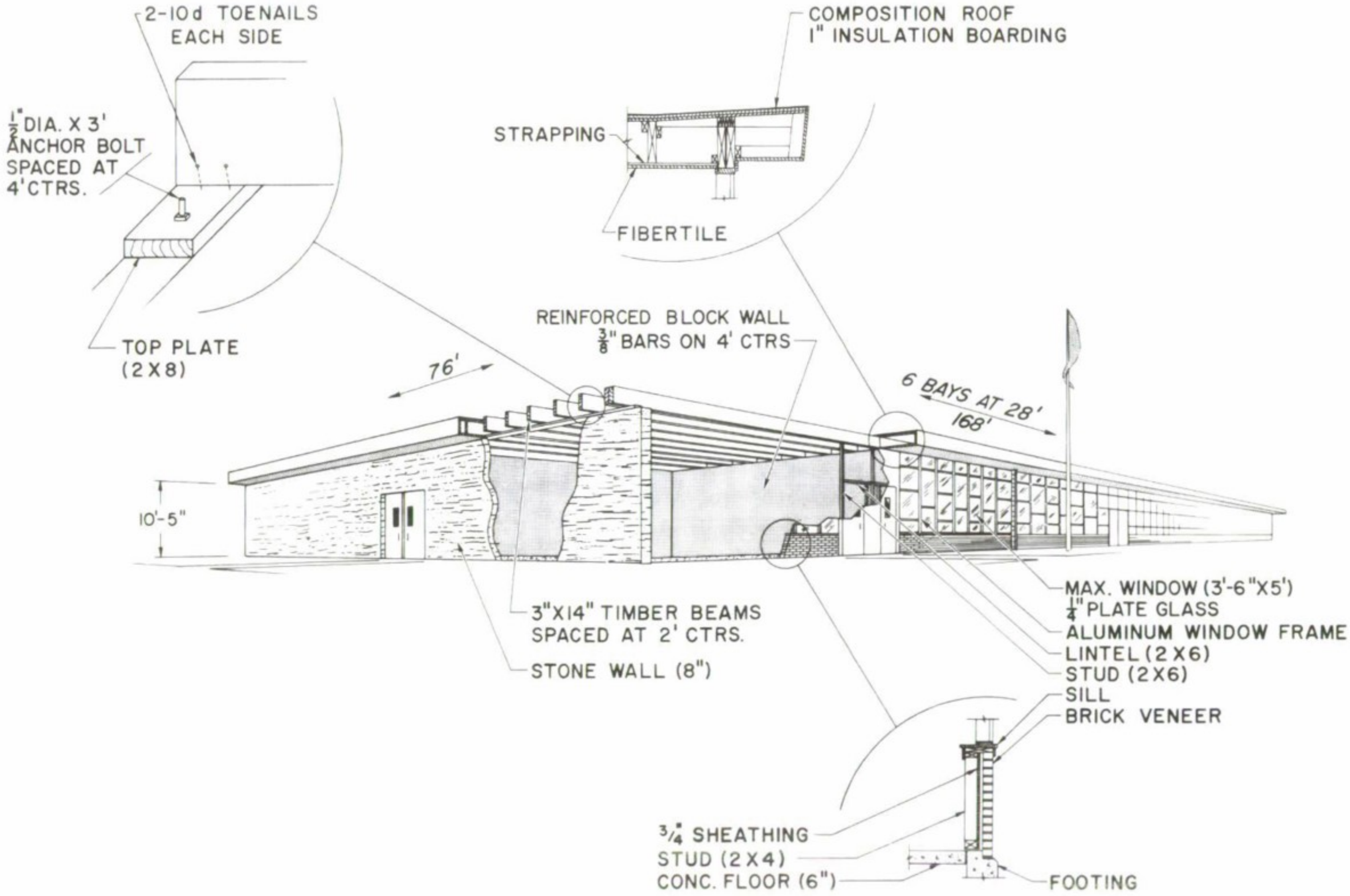


Figure 3. Typical Elementary School

on the bottom of the rafters. The total roof weight of a 2-foot section is approximately 30 to 45 lbs/ft of beam.

The end wall is 8 inches thick with stone mortared together with no reinforcing. It is 10 feet 6 inches high and contains no windows. It has the same simple support conditions as the house brick wall.

The windows in the front wall vary somewhat in size, the maximum being approximately 3 feet 6 inches by 5 feet. All windows are 1/4-inch plate glass supported by aluminum frames.

The school roof and stone wall are the most likely structural components to collapse under a given blast loading. The windows, of course, will fracture and present an appreciable glass fragment hazard; however, the loss of the windows and window frame portion of the front wall will not cause collapse of the roof because of the orientation of the roof support beams. Blast damage levels corresponding to cracking the roof rafters and/or severely cracking the stone wall therefore have been defined as acceptable criteria on which to establish minimum separation distances. To reemphasize, a deflection of the center of the 8-inch stone wall of approximately 5 inches is considered sufficient to seriously crack the wall but not to cause partial or complete collapse.

1. Analysis of the Stone Wall

The resistance functions and the unit impulse required to severely crack the stone wall were computed using the model for masonry walls discussed in Reference 1. As in the treatment of brick and concrete walls, a steady pressure of approximately 0.5 psi was assumed to be required to cause tensile bond failure in the mortar. In the programmed analytical model, then, a requirement of at least a 0.5 psi average overpressure throughout a blast loading interval equal to the calculated critical period was stipulated. As in the analysis of the other types of wall section, the effective reflected impulse was estimated as the integral of the overpressure function from time $t = 0$ to a time at which the overpressure level decreases to 0.2 psi.

Equations (1) and (2) are used to obtain the critical period for a 1-inch wide column of stone wall, analyzed as a uniformly

loaded beam. From one to four values each of Young's modulus and the tensile bond failure stress for mortar must be entered on cards 46 and 47.

The lack of openings in the stone wall prevents back pressure from building up on the inside of the stone wall; thus, the blast loading on the front face of the wall is the only consideration. As indicated in the treatment of other wall sections, the required critical impulse for each set of parameter values depends to a large degree upon the blast loading on the roof. Under the assumption that the stone wall supports one-half of each roof section, the computer program calculates each unit impulse requirement based on one-half of the contribution (per inch of stone wall) of the calculated maximum average pressure on the roof. This procedure is clearly defined in Reference 1.

2. Analysis of the School Roof

The school roof beams are analyzed as being uniformly loaded. Their critical periods and critical impulse calculations are straightforward using equations (1) through (10). Up to four parameter estimations of E, w, and σ can be entered on cards 48, 49, and 50. As is the case in all target analysis subroutines in this model, once a separation distance is determined which results in the defined damage for one of the vulnerable components of that target, the computed impulse on the other component(s), at that distance, and its respective critical impulse, for all parameter variations considered, are compared. For the parameter variations considered for the school wall and roof in Reference 1, it was found that the school wall suffered the defined acceptable damage in all cases prior to achieving the defined damage to the school roof.

D. OFFICE BUILDING - HALF WALL WITH WINDOWS

The analysis of the concrete block walls (Figure 4) is conducted by the computer program under the same general set of assumptions as used in the treatment of the other masonry walls. Selected values of E and the tensile strength of the half wall are entered on cards 51 and 52. A net loading concept is used in which the pressure buildup on the rear surface of the half wall is subtracted from the overpressure

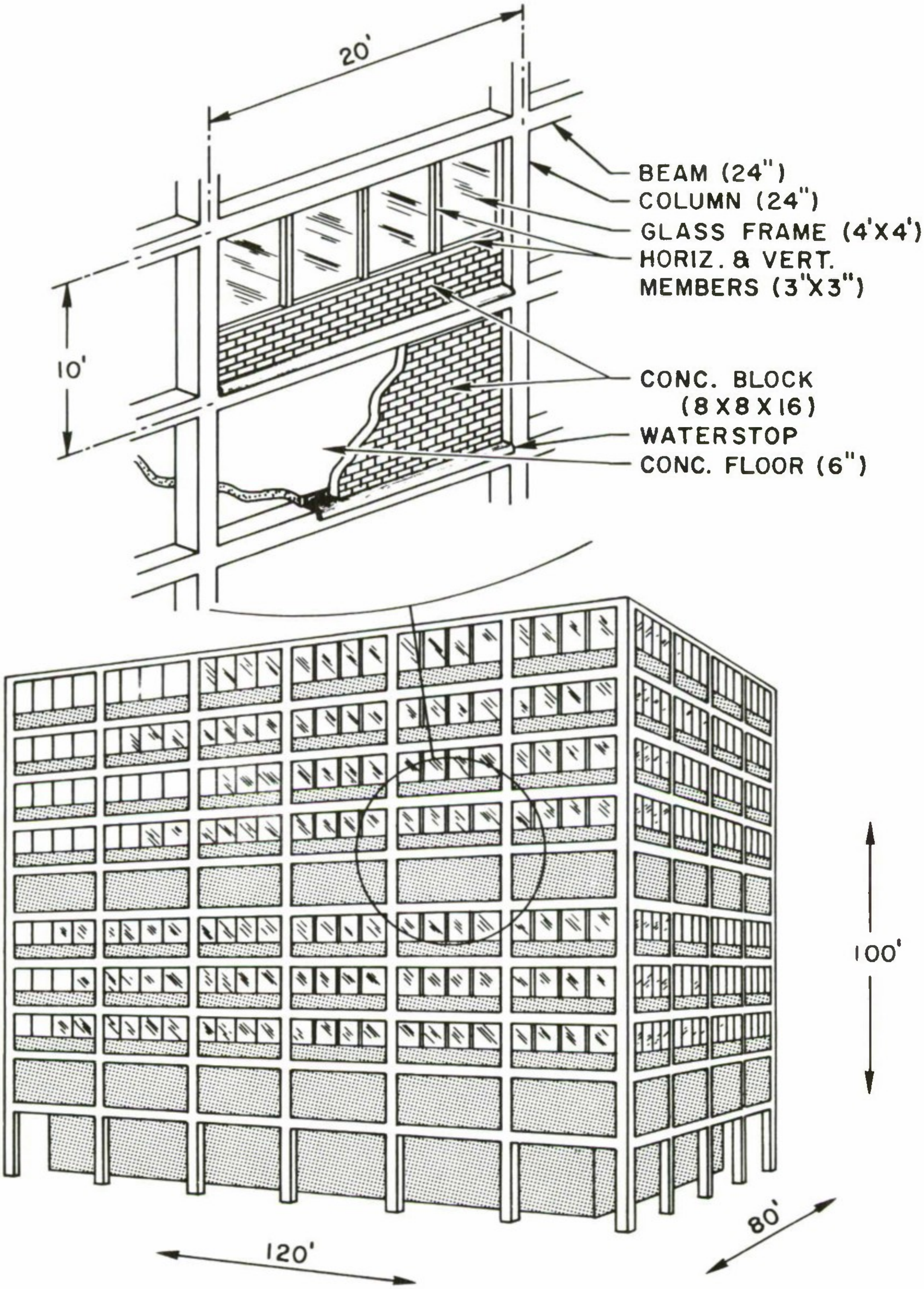


Figure 4. Multi-Story Building

function on the front surface. Again, the reflected impulse values are calculated by integrating the net overpressure function from time t = 0 to a time at which the overpressure decays to 0.2 psi.

E. OFFICE BUILDING - FULL WALL WITH NO OPENINGS

The full office wall is an arching type wall under blast loading in that, since it is constructed tightly between two immovable concrete columns, some mortar must be crushed in order to deflect the wall to a point at which serious cracking will occur. The models for the analysis of an arching wall are taken from Reference 7 and are described in detail in Reference 1. Based on mortar sample crushing tests, a steady pressure of approximately 5 psi must be maintained for a significant period so that sufficient crushing of the mortar at the top and bottom of the wall may take place. In the computer analysis, it is assumed that this average pressure must be maintained over a time interval equal to its calculated critical period. Up to four values of E and tensile strength are entered on input cards 53 and 54. The reflected impulse for each charge separation distance and set of parameter values is calculated using a front surface blast loading model in which the overpressure function is integrated to a time at which the function decreases to 0.2 psi.

Comparison of separation distances for the full office wall and half wall can only be obtained by requesting both subroutines with the control card.

F. PASSENGER BUS

The prevention of overturning is the basis on which acceptable damage criteria have been established for the vehicular targets--the passenger bus, camper-pickup unit, and the mobile home. The pressure-impulse requirements to overturn these targets are therefore determined in this analysis, and the acceptable damage level arbitrarily established as being that damage associated with 80 percent of the reflected impulse necessary to overturn each vehicle. With such forces imparted to the vehicle, some deformation of the exposed sidewalls, window breakage, and the dislocation of some internal fixtures will probably occur, especially for the smaller charges.

These effects, however, should not present an unacceptable hazard to the occupants.

The bus analyzed is a rather standard intercity highway bus (Figure 5). The external skin sections of the bus are attached to a rather light but extensive space frame composed of many small members, primarily square or rectangular steel tubing. There is no main frame such as is commonly found in trucks and older cars. The outer skin, either steel or aluminum, and the plywood passenger and baggage floors are rigidly attached to the framework and provide part of the structural strength.

The empty bus weighs between 18,000 and 22,000 pounds, and when fully loaded with 40 people and baggage, an estimated weight of about 30,000 pounds is attained. The center of gravity is estimated from 40 to 46 inches above the ground plane.

The reflected impulse needed to overturn a stationary target requires a determination of the mass distribution of the target and the location of the center of gravity. The height of the center of gravity above the point of rotation, A, in the ground plane is designated as h_g and the distance, in the ground plane, from the center of gravity to the point of rotation as d. The distance, $d_o = \sqrt{d^2+h_g^2}-h_g$, represents the distance the center of gravity must rise so that it is directly above point A, at which point gravitational forces will overturn the target. For most targets, point A is a point in the ground plane directly below the outside surface plane of the vehicle.

The work, W, done in overturning the target is

$$W = d_o \cdot (\text{weight of the vehicle, } w) \quad . \qquad (11)$$

When a sufficient impulse is applied to the target rapidly, it will give the target an angular velocity, ω, great enough to permit inertial forces to complete the overturning action. The angular velocity will be sufficient when the kinetic energy is greater than the work required from equation (11), where

$$KE = 1/2 \; I_A \omega^2 \quad . \qquad (12)$$

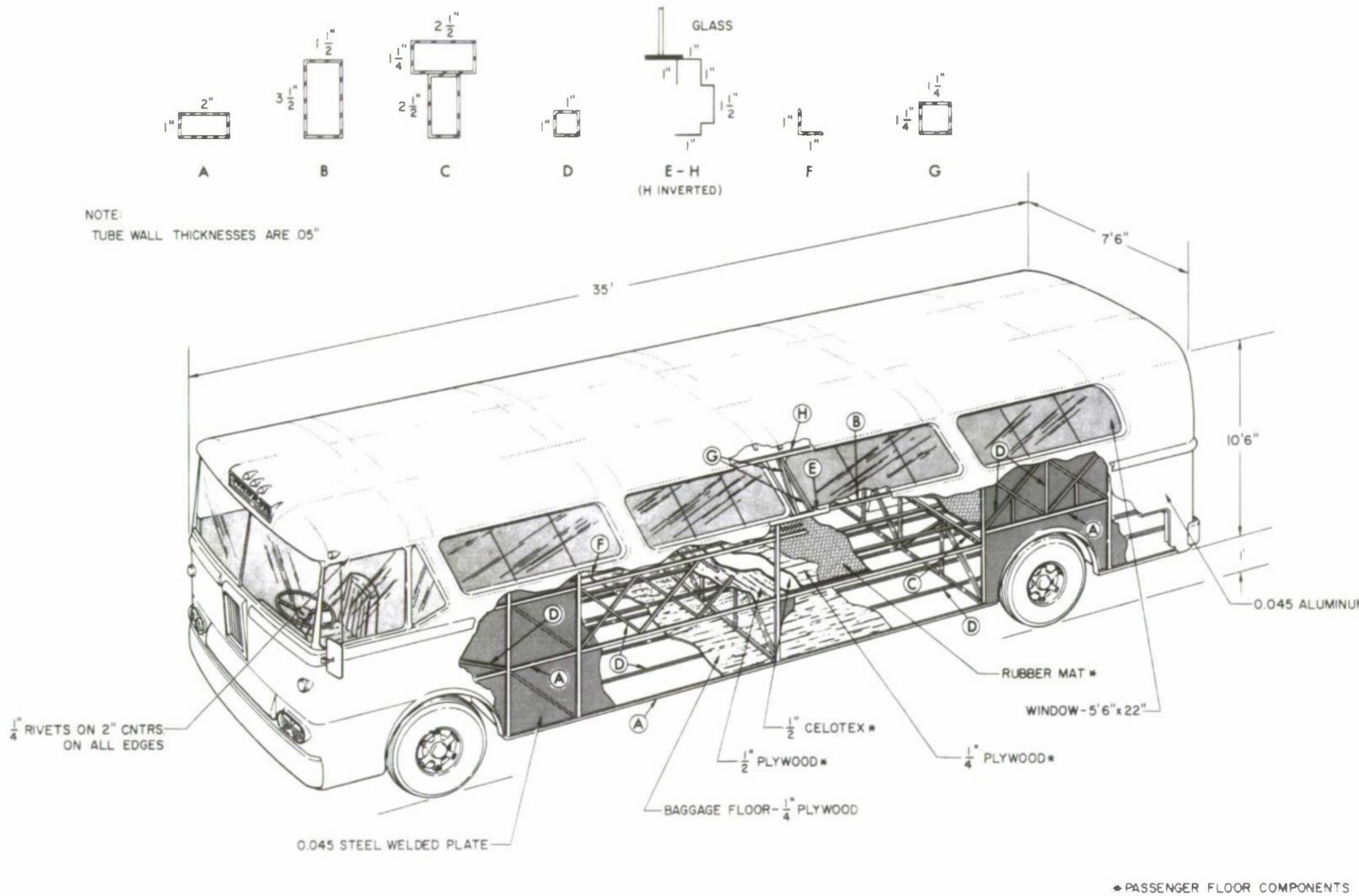


Figure 5. Passenger Bus

The value I_A is the moment of inertia about point A and is given as

$$I_A = m \left(\frac{b^2+h^2}{12} + c^2 \right) \tag{13}$$

where:

m = mass of the target

b = width of the target

h = height of the target

c = the transfer axis distance; $c = d_o + h_g$.

By equating the required work, W, with the kinetic energy and substituting equation (13) into (12), an expression for the required angular velocity, ω, to overturn the target is obtained:

$$\omega = [2W/I_A]^{1/2} = \left[\frac{2\ d_o w}{I_A} \right]^{1/2} . \tag{14}$$

The required unit impulse (psi-msec), H, required to produce this angular velocity is

$$H = \frac{1000 \cdot I_A \cdot \omega}{h_c \cdot (\text{presented area of the target})} \tag{15}$$

where h_c represents the height above the ground where the center of the blast pressure is applied.

The computed reflected impulses required to overturn the stationary bus were all well within the present quantity-distance criteria for the five charge sizes considered in Reference 1. The bus therefore was analyzed under more vulnerable conditions, that of being in a 460-foot radius turn at 50 mph.

In order to select a typical turning condition for the bus, it was experimentally determined, that for normal safe driving, the resultant force exerted on a vehicle by the road (composed of the centripetal force applied in the horizontal plane and

the weight reaction force applied vertically) would be inclined a maximum of 20 degrees from the vertical. This would occur at different speeds for different radius curves, but at 50 mph is associated with a 460-foot radius curve. The centripetal force corresponding to 20 degrees is w·tan 20 degrees = .364 w. A condition of "unstable equilibrium" can be used which is represented, for a stationary bus, by a tipping to the point where the center of gravity is directly above point A; for a bus in a turn, unstable equilibrium will occur when a blast on the inner side of the curve has tipped the bus such that the sum of the moments about A, of the centrifugal force and the weight, equal zero. Thus, the bus in a 50-mph, 460-foot radius turn is at unstable equilibrium when:

$$.364w\ (\sqrt{d^2+h_g^2}\cdot\sin\theta) - w\ (\sqrt{d^2+h_g^2}\cos\theta) = 0$$

$$.364w = \cot\theta \tag{16}$$

$$\theta = 70 \text{ degrees}$$

where θ is the angle between the ground plane and a line connecting the displaced center of gravity with the point of rotation A, and d and h_g are as previously defined. Therefore, gravity must rise a distance

$$d_o = (\sin\theta\sqrt{d^2+h_g^2}) - h_g\ .$$

The distance the c.g. moves in the direction of the centrifugal force becomes

$$d_c = \cos\theta\ \sqrt{d^2+h_g^2}\ .$$

The work done by the centrifugal force is therefore

$$W_c = d_c\ (.364\ w)\ . \tag{17}$$

The above work is subtracted from the total work requirement calculated with equation (11) to determine the work required only by the blast force to overturn the bus. Using this modified work calculation in equations (13), (14), and (15) results in a determination of the reflected impulse calculation required to overturn the bus moving in the 460-foot radius turn.

In the computer analysis the location of the c.g. of the bus and its weight are treated as random variables. Up to four values of these parameters are entered on cards 55 and 56. The net loading concept is used in determining the reflected impulse imparted to the bus for each specified quantity-distance combination and set of parameter values. As in the treatment of walls, the "effective impulse" is assumed to be that impulse obtained by integrating the net overpressure function to a point at which it is $\leq .2$ psi. This concept was used for all vehicular targets.

G. CAMPER-PICKUP UNIT

The structural detail of the camper-pickup unit is illustrated in Figure 6. The side walls are composed of a very light, non-structural, aluminum outer skin; a very irregular glued and stapled framework of 1- by 2-inch, 2- by 2-inch, and 2- by 3-inch wood members with spacing to accommodate the windows, cupboards, etc.; and an inner covering of 1/8- or 3/16-inch plywood glued and nailed to the framework. In the interior there are numerous cupboards, seats, counters, etc., which contribute considerable strength and stiffness to the side walls.

The minimum separation distance for this unit for a specific charge was determined, as previously stated, as the distance at which 80 percent of the reflected impulse required to overturn the unit is attained. Again, the permanent deformation of the side walls and glass breakage which will occur at this point are considered acceptable.

The reflected impulse required to overturn the camper-pickup unit can be determined through straightforward use of equations (11) through (15) presented in the previous section.

Separate estimates of the camper c.g. location, truck c.g. location, camper weight, and truck weight are used, and up to four values each are specified on input data cards 56 through 60. The net blast loading concept is used for the camper-pickup unit and the computed reflected impulse achieved for a given charge-distance combination computed from the resultant net loading function.

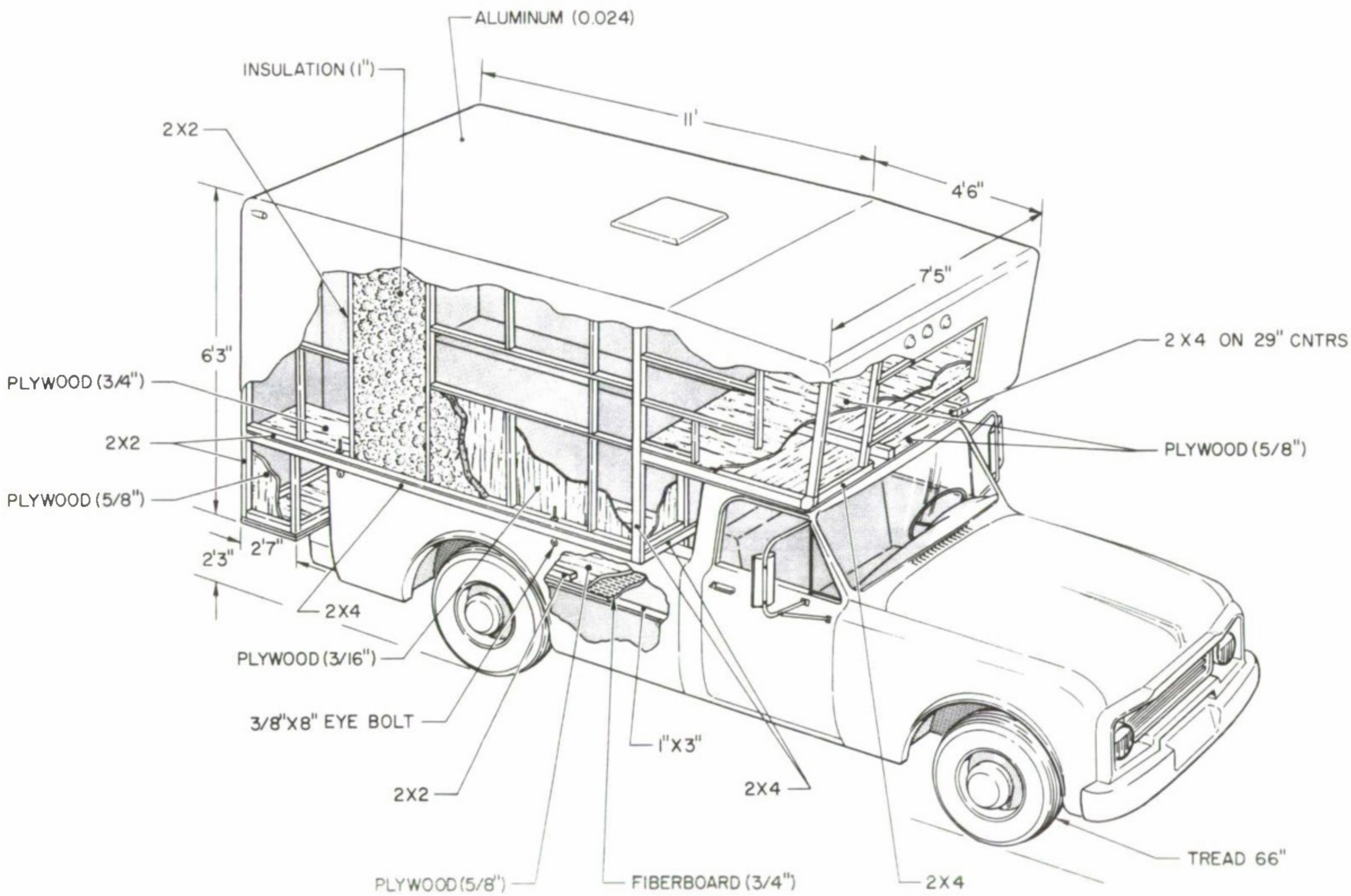


Figure 6. Camper-Pickup

H. MOBILE HOME

The mobile home (Figure 7) has a main frame consisting of two light but deep channels, with cross channels welded between these main frame members in the same plane. On top of the cross channels, 2- by 4-inch wood members run lengthwise on 16-inch centers; they are stabilized by 1- by 3-inch wood members placed at right angles, on 24-inch centers. Covering these are 1/2-inch plywood sheeting and non-structural finish flooring materials.

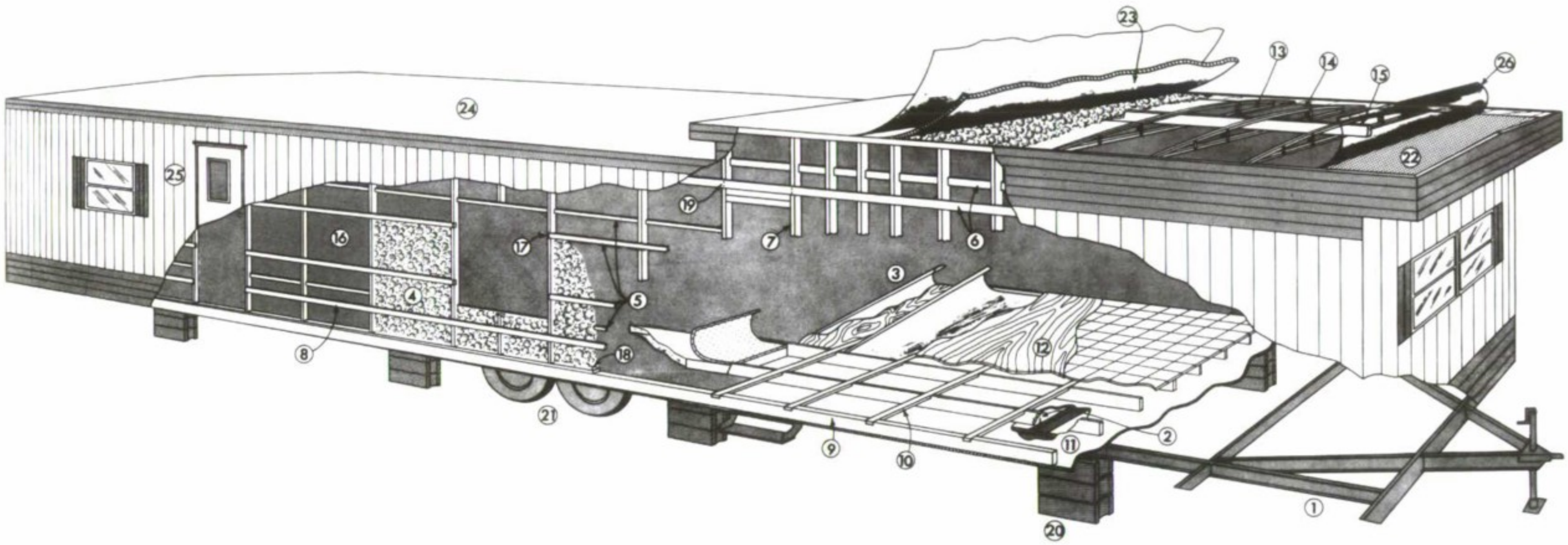
The side walls have a non-structural outer metal skin, 2- by 3-inch studs on 16-inch centers with several 1- by 2-inch stringers, and an inner covering of nailed and glued 3/16-inch plywood. The various cupboards, partitions, etc., have not been illustrated. The roof has light truss cross members composed of 2- by 2-inch chords and metal web members. There is a 2- by 4-inch wood member running lengthwise through the center of the trusses to stabilize them. The roof is not particularly vulnerable to blast loading because the shock wave is assumed to impinge on the side of the trailer and the reflected pressure on the roof is only very slightly higher than the incident pressure.

Up to four values of the c.g. location and mobile home weight must be entered on input data cards 61 and 62. The net loading concept is also used in determining the reflected impulse imparted to the mobile home for a specified quantity-distance combination.

I. EXPLOSIVE STORAGE IGLOO

The explosives storage igloo is supported by a No. 1 gage corrugated steel arch with a 2-foot minimum earth cover. The igloo has a 13-foot radius and is 59 feet long (inside dimension). The front concrete wall is 12 inches thick with two 5- by 10-foot steel doors opening outward. The outside of the door is covered with 3/8-inch steel plate. Insulation and 16-gage steel plate comprise the inside portions of the door. This igloo construction is shown in Figure 8.

The 3-inch thick igloo door is composed of a 3/8-inch outer steel plate welded to a 3-inch deep, 6-lb/ft steel channel forming the perimeter of the door. One inch of insulation is



1 8 channel, 8.5 pounds per foot.
2 5/16" dia. x 3" long lag screw thru each cross frame member into each 2x4.
3 Triple floor insulation, surface next to frame is asphalt impregnated board. Blanket of 3.25 high density fiberglass is laid over the insulation board. Polyethylene vapor barrier. Dead air space between vapor barrier and wood flooring.
4 Sidewall insulation, high density fiberglass combined with reflective aluminum exterior. Fiberglass is stapled to prevent sag.
5 1"x2" kiln dried spruce, spaced as needed.
6 1"x3" kiln dried spruce, spaced as needed.
7 2"x3" kiln dried spruce, spaced 16" on center or as needed.
8 1"x3" kiln dried spruce, spaced as needed.
9 2"x4" kiln dried spruce, spaced 16" on center.
10 1"x3" kiln dried spruce, spaced 24" on center.
11 5/8" asphalt celotex.
12 1/2" plywood.
13 2"x2" kiln dried spruce
14 2"x2" kiln dried spruce
15 2"x4" kiln dried spruce
16 3/16" hardwood veneer panels. All wall panels are glued and nailed.
17 Two 6d nails.
18 One 10d nail spaced 8" thru 2x3 plate into floor edge 2x4.
19 Two 8d nails.
20 Concrete leveling blocks spaced 8 places.
21 Tires clear of ground when on concrete blocks.
22 Blanket of fiberglass.
23 3/8" plywood.
24 28 gage steel roof. The roof is coated with aluminized asphalt compound for added sound protection and sealer.
25 .02 inch aluminum side panels with baked on, prefinished color surface. Side walls are made with overlapping seams to insure water tight construction. Fastened with 3/16" by 1" hex head sheet metal screws.
26 Polyethylene vapor barrier attached to ceiling joist.

Figure 7. Mobile Home

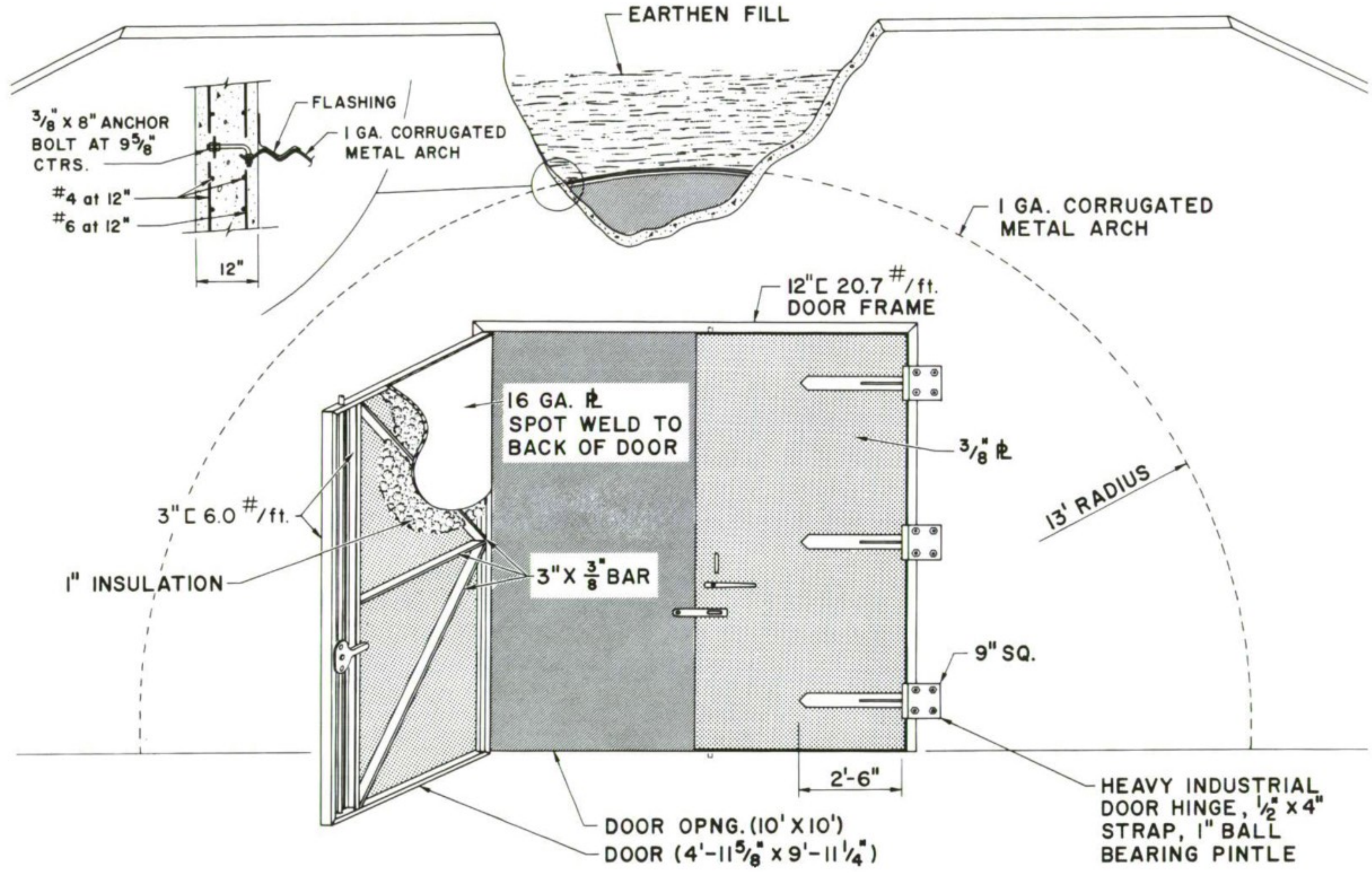


Figure 8. Standard Explosive Storage Igloo, Front

glued to the inside of a 3/8-inch plate, and a 16-gage plate is tack-welded on the backside of the channel. The door is held in place by three hinges with 1-inch diameter pins. Pins within the door of 1-3/8-inch diameter extend 1-1/2 inches into reinforced holes in the door frame.

The acceptable damage levels were defined as severely cracking the igloo concrete wall or dislodging the igloo doors--whichever occurs first. In Reference 1 three types of failure were evaluated; these are

1. Deformation of the door such that the pins pulled from their sockets in the door frame,

2. Shearing of the pins between the door and the socket, and

3. Failure of the concrete wall around the door.

Analyses of shear pin failure and of fracturing the concrete wall, by Johansen's yield line theory, indicate that deformation of the door so that the pins are dislodged will occur first.

An 8-inch deflection of the door is necessary in order to dislodge the pins from the holes in the door frame. Analyzed as two rigid halves with a plastic hinge in the middle, the work W required to achieve the stipulated deflection becomes $W = M\theta$; where M is the plastic moment needed to deform the central section of the door, and θ is the central deflection angle. The required unit impulse is then determined by using equation (10). Values of Young's modulus of the steel door are entered on input data card number 63.

The reflected impulses which result in deformation of the steel door, so that the pins are dislodged, are used as a basis for establishing quantity-distance specifications in this program. Using $E = 5 \times 10^4$ psi in Reference 1, a critical impulse of 139 psi-msec was obtained.

J. PERSONNEL

The "standard man" as used in several military target descriptions and vulnerability studies is illustrated in Figure 9.

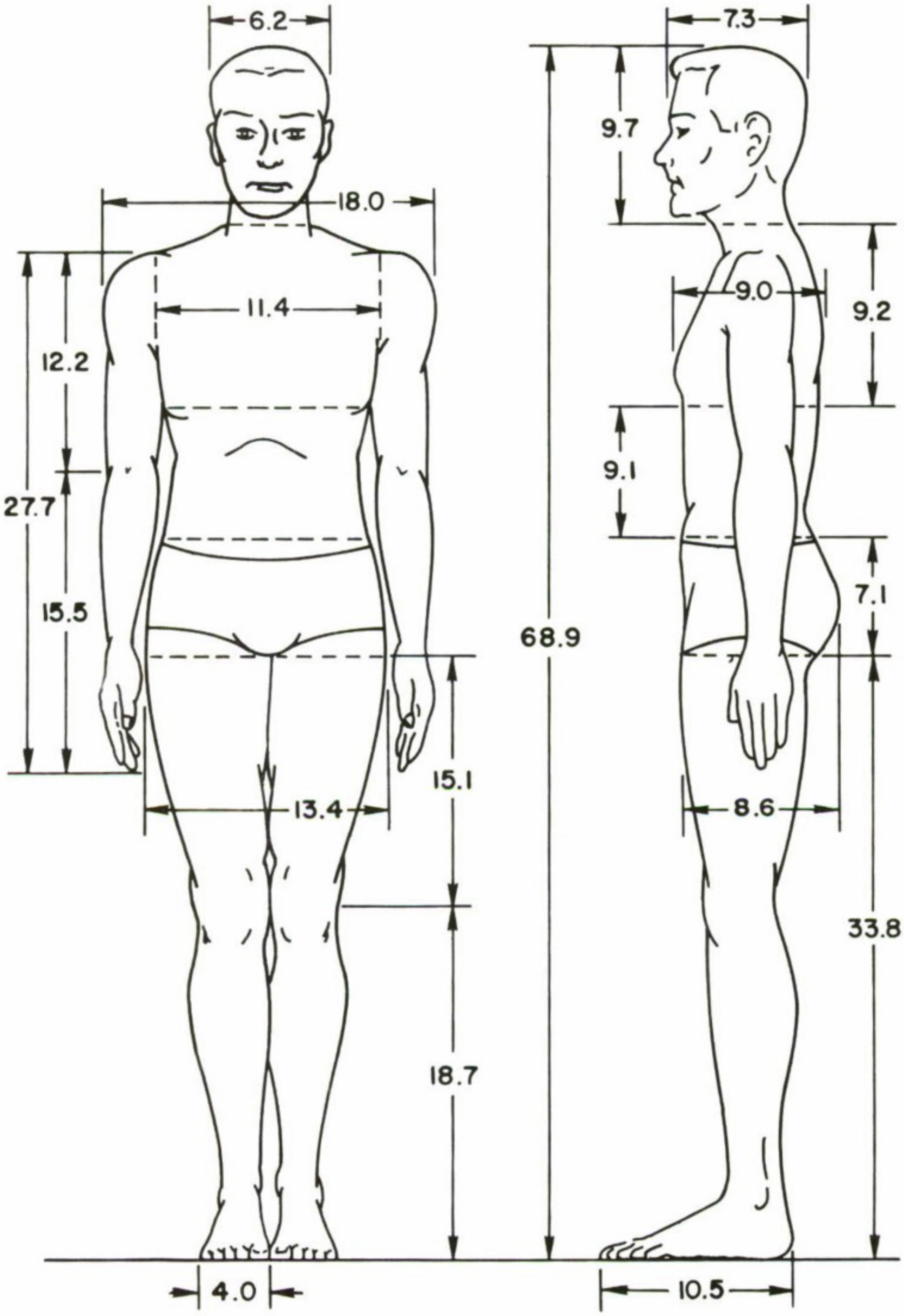


Figure 9. Standard Man

The quantity-distance specifications for the personnel target have been established so as to prevent his being thrown to the ground, down stairs, or against nearby structures. Lovelace Foundation studies [8] have indicated that the translation velocity at which man begins to be subjected to these dangers is approximately 3.5 fps. The "acceptable damage" criterion thus is based on the reflected impulse which results in the translation of a man at a maximum velocity of 3.5 fps.

Dynamic overpressure is the main factor in the translation of objects in a blast wave. In order to translate a man of given weight and presented area, the impulse associated with the integration of the dynamic overpressure function must be greater than the product of the mass of the man and his translation velocity or

$$PA \cdot \int q(t)\, dt > m \cdot v \tag{18}$$

where:

PA = presented area of the man (in^2)

$q(t)$ = dynamic overpressure function

m = mass of the man

v = translation velocity.

The above equation allows velocity to be expressed as a function of time; the computer program integrates that function to obtain a translation distance associated with a maximum velocity of 3.5 fps. The maximum acceleration a_{mx} over the calculated translation distance becomes

$$a_{mx} = \frac{F_{mx}}{m} \tag{19}$$

where:

F_{mx} = force given by $Q_o \cdot P_a$, and

Q_o = peak dynamic overpressure.

Up to four values of the man's weight and his presented area are entered on cards 64 and 65. In the analysis a peak reflected overpressure of 5.0 psi is used as the threshold of eardrum rupture. In cases where only eardrum hazards occur, the maximum distance from the charge where 5.0 psi reflected pressure occurs is designated as the separation distance criterion.

K. COMMERCIAL AIRCRAFT

The Boeing 707 aircraft is used as the representative large commercial jet aircraft. A detailed drawing of each section shown in Figure 10 is presented in Reference 1.

The fuselage shell is of the semi-monocoque type with aluminum skin and clad 7075-T6 longitudinal stringers. The shell is stiffened circumferentially by bulkheads and 7075-T6 "Z" section frames. The wing is a full-cantilever, semi-monocoque, cellular structure tapering in both platform and depth. The skin coverings vary in thickness from 0.06 to 0.45 inch. The horizontal stabilizer and vertical fin of the tail are of two-spar construction. There is no other spanwise stiffening.

The University of Dayton Research Institute has conducted an extensive study of the static and dynamic loadings required to fail the most vulnerable skin panels and other components on this aircraft [9]. The first step in their study was to perform stress analyses on several of the weaker fuselage skin panels. Since the skin panels transmit the blast loading to the internal structure, the location of the critical skin panels gives an indication of areas in which the substructure should be investigated. Complete analyses were conducted on these components. Based on their conclusions, a large fuselage skin panel located between fuselage stations 1060 and 1080 on the underside of section C fuselage shown in Figure 10 was shown to be the most critical or vulnerable skin panel. Permanent deformation of this panel occurs under a 2.3 psi reflected overpressure.

It is highly probable that the aircraft can undergo serious deformation of many skin panels without approaching a state causing loss of control. Therefore, threshold deformation of the substructure supporting the weakest skin panel has been defined as the acceptable damage level.

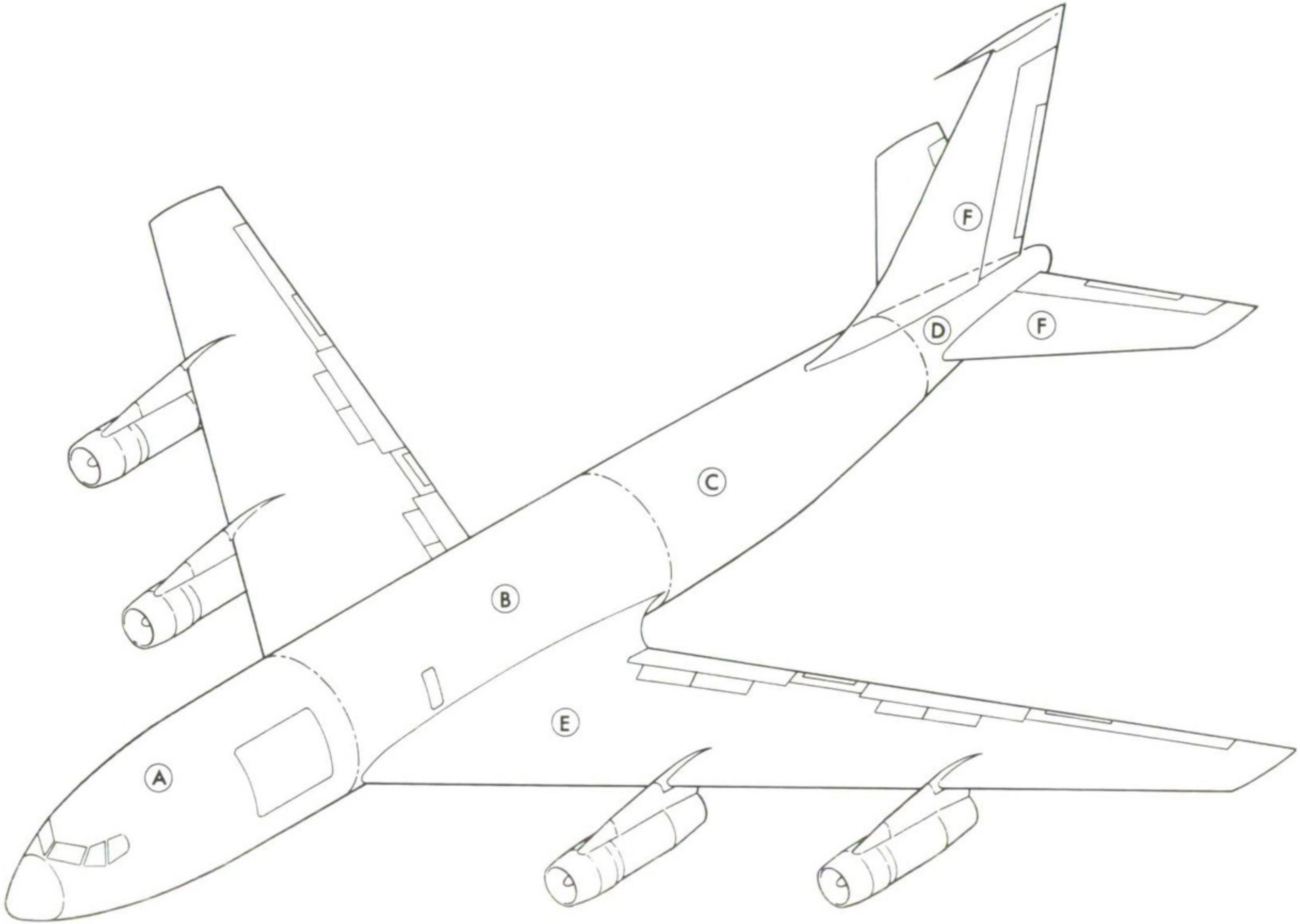


Figure 10. Boeing 707 Aircraft

The static loading required to permanently deform the frame section supporting the vulnerable skin panels described above is 7.23 psi. The dynamic response of this panel is described as a function of the ratio of the positive duration of the blast wave to the natural period of the frame member. The natural period of the frame member T is given by:

$$T = 2\Pi/\eta \quad , \tag{20}$$

where:

$$\eta = 2.68 \sqrt{\frac{EIg}{A\rho R^4}} \tag{21}$$

where, as in (21), and as previously defined:

E = Young's modulus

I = cross-sectional moment of inertia

g = gravitation constant

A = cross-sectional area

ρ = density of the frame material

R = radius of the frame.

The relationship between the ratio of the positive duration and the natural period of the frame and the dynamic loading factor, α, is shown in Reference 1, page 94 and Reference 9. Ten values are entered on input card 67. These correspond to the range $1/2 \leq \alpha < 5$ in 1/2 unit increments. The ten values listed under the card format definition must be used.

Up to four estimates of E for the aluminum frame member may be entered on card 66. These values lie in a range of 10.0 to 12.0 million psi. For $E = 10.6 \times 10^6$ psi, a natural period of 36 msec is calculated for the frame member.

A quantity-distance specification for each charge size is computed as the distance at which the incident overpressure, P_o, in (21) satisfies the inequality,

$$D_F \cdot (R_F \cdot P_o) > 7.23 \text{ psi} \tag{22}$$

where:

D_F = dynamic response factor and

R_F = reflection factor.

For a normal side-on impingement of the blast wave on the fuselage, the reflection coefficient for the panel under investigation is determined from an angle of incidence of approximately 63 degrees.

V. REFERENCES

1. Custard, G. H., J. D. Donahue, and J. R. Thayer, "Evaluation of Explosives Safety Criteria", Falcon Research and Development Company, Denver, Colorado; Armed Services Explosive Safety Board, Washington, D. C., March 1970.

2. Johnson, O. T., "A Blast Damage Relationship (U)", BRL Report No. 1389, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, September 1967 (Confidential).

3. Kingery, C. N., "Parametric Analysis of Sub-Kiloton Nuclear and High Explosive Air Blast", BRL Report 1393, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland, February 1968.

4. "Strength Values of Clear Wood and Related Factors", Agriculture Handbook No. 72, Forest Products Laboratory.

5. Sewell, R. G. S., "A Blast Damage Criterion (U)", Weapons Development Department, Naval Weapons Center, China Lake, California, AD 349 335, March 1964 (Confidential).

6. The Effects of Nuclear Weapons, Atomic Energy Commission, 1962.

7. Wiehle, C. K., and J. L. Bockholt, "Existing Structures Evaluation, Part I. Walls", SRI Project No. MU6300-020, Stanford Research Institute, Menlo Park, California, for the OCD, November 1968.

8. Bowen, I. G., et al., "Translation Effects on Air Blast From High Explosives", Lovelace Foundation for Medical Education and Research, Albuquerque, New Mexico, DASA Report 1336, November 1962.

9. Schwartz, R. B., "Safe Overpressure Limits for the C-135 Aircraft Exposed to Nuclear Detonation", Technical Report SEG-TR-64-69, University of Dayton Research Institute, January 1965, AD 459 375.

10. Naval Ordnance Laboratory, "Explosives Effects and Properties (U)", NOLTR 65-218, White Oak, Maryland, February 1967 (Confidential).

VI. FLOW CHARTS AND SOURCE PROGRAM

Flow charts and a source deck listing of this program are provided in this section. Block numbers and subtitles have been used liberally through the flow charts so as to facilitate an understanding to the desired computation. Blocks applicable to each subroutine are shown in Table II.

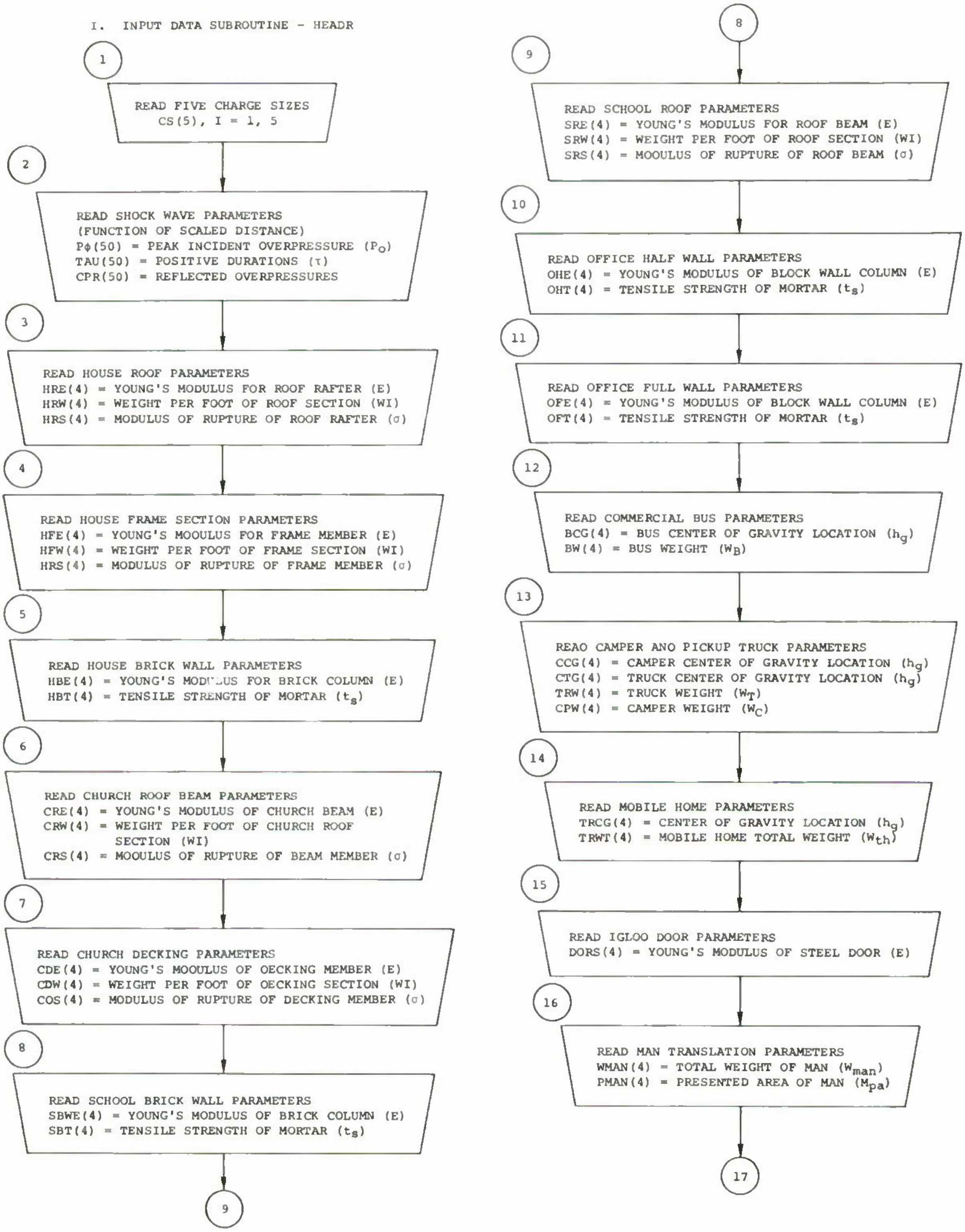
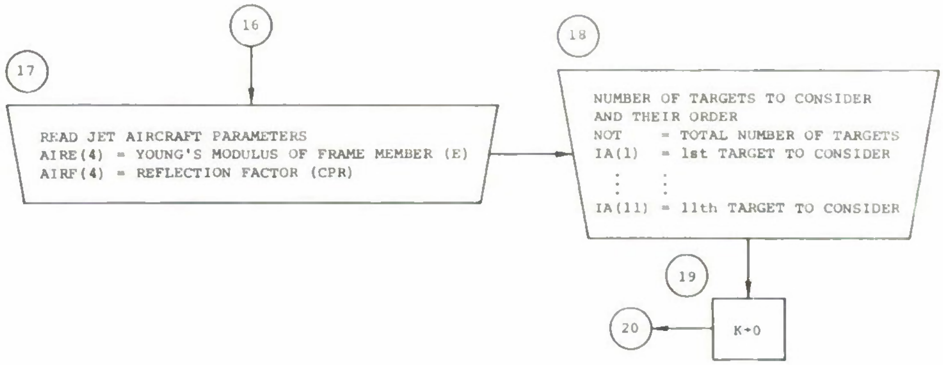


Figure 11. Flow Charts of the Quantity-Distance Computer Program



11. TARGET SELECTION SUBROUTINE - CALLR

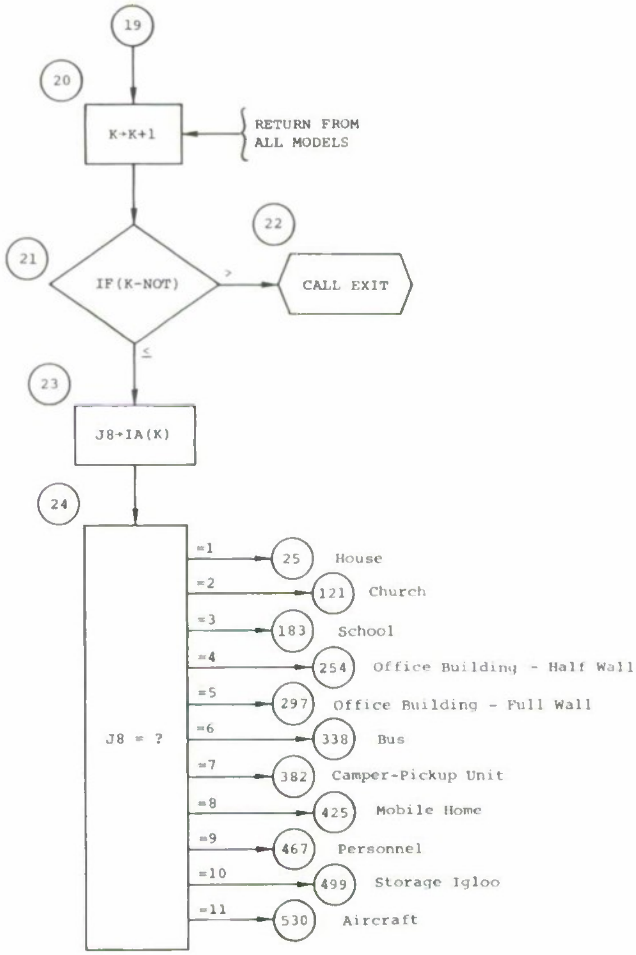


Figure 11 (Continued)

III. SPLIT-LEVEL HOUSE ANALYSIS SUBROUTINE - HOUSE

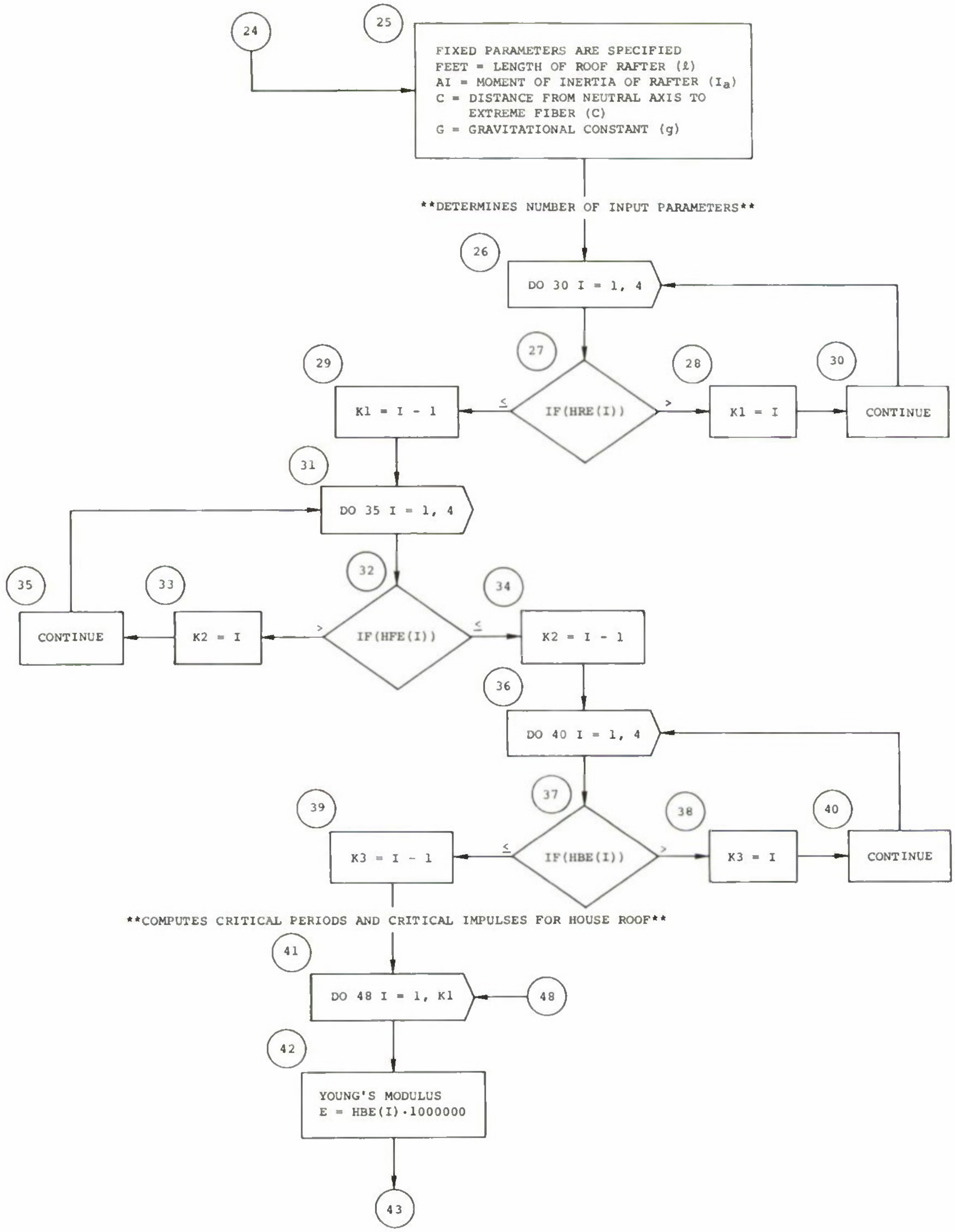


Figure 11 (Continued)

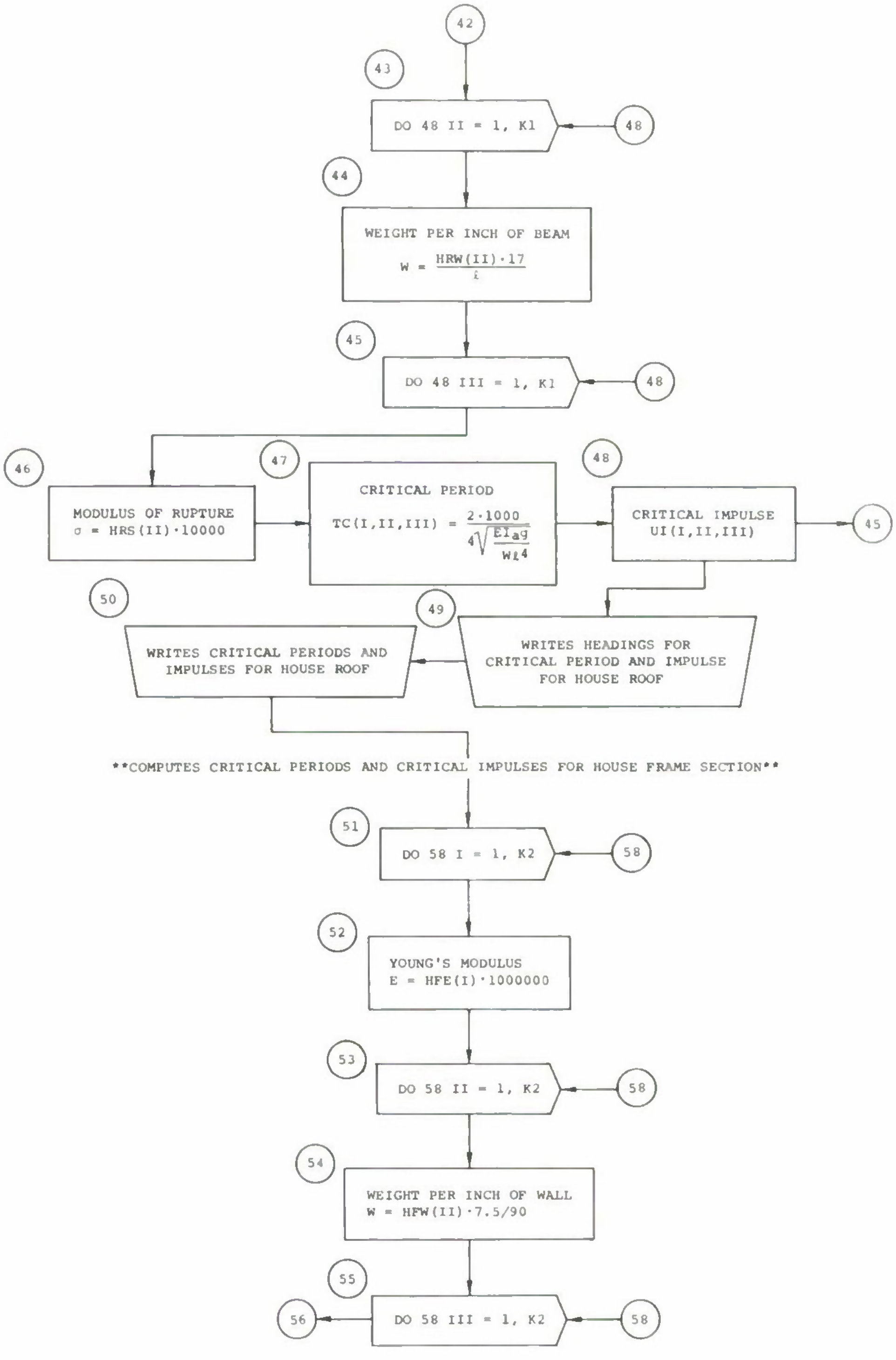
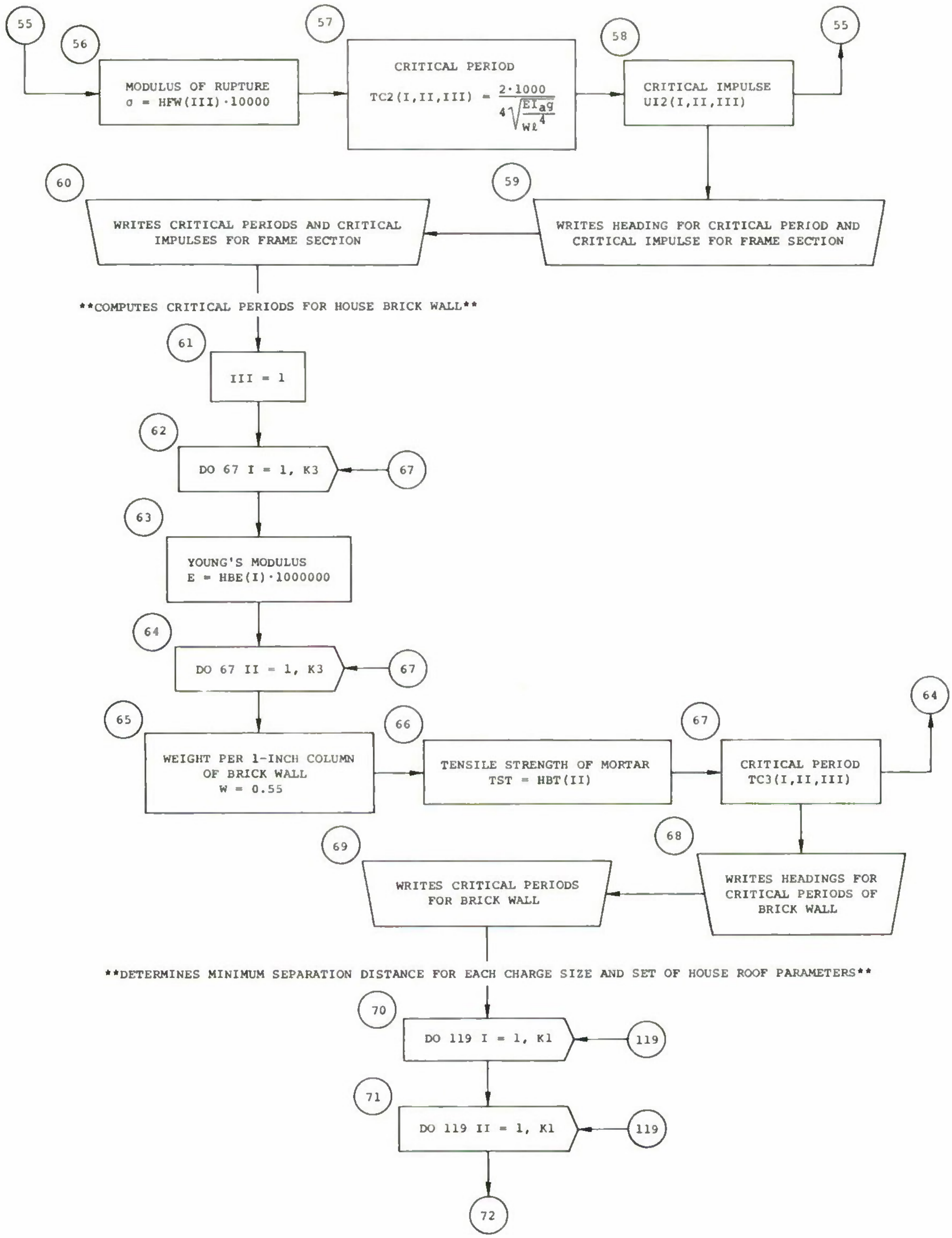


Figure 11 (Continued)



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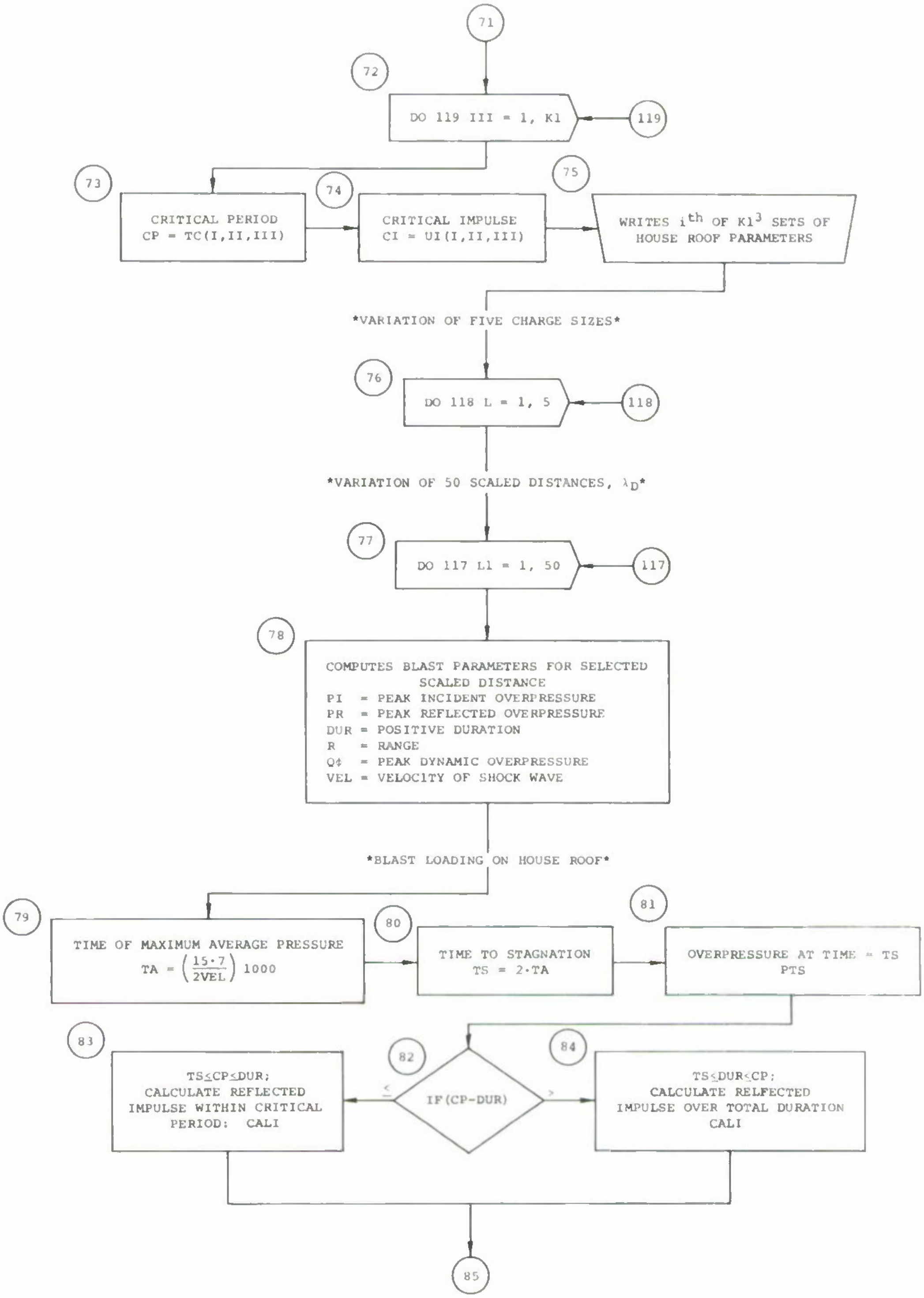

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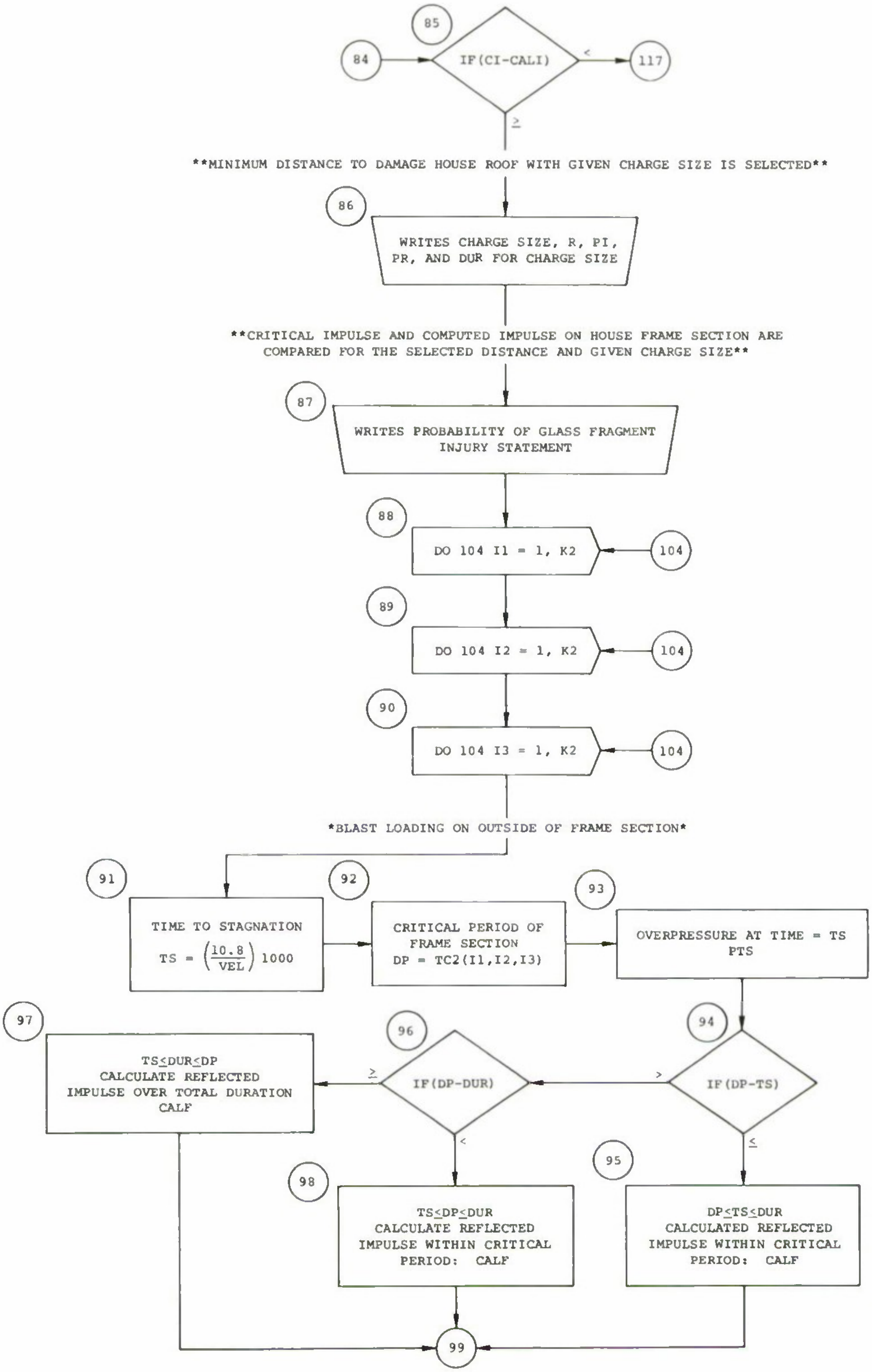


Figure 11 (Continued)

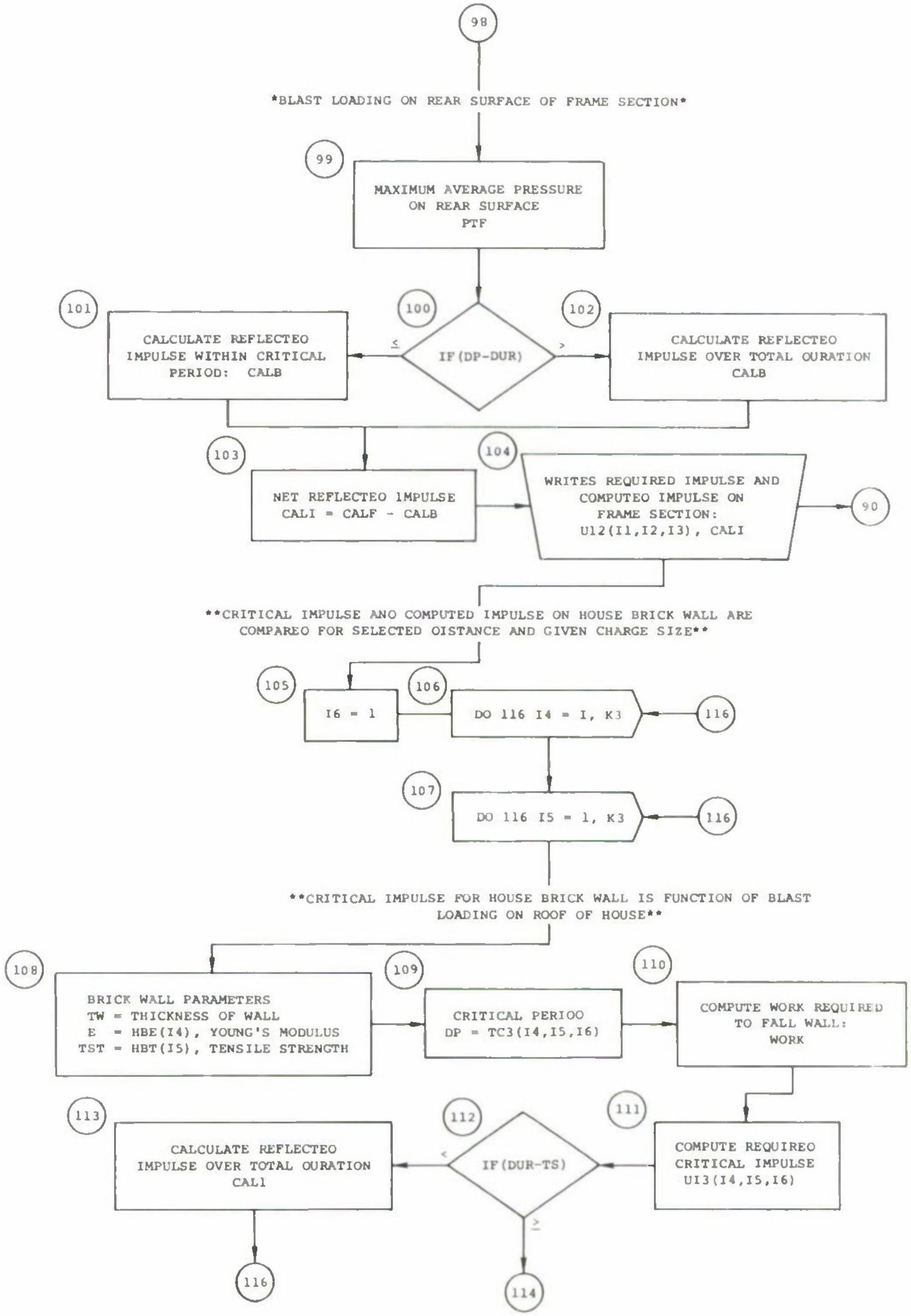
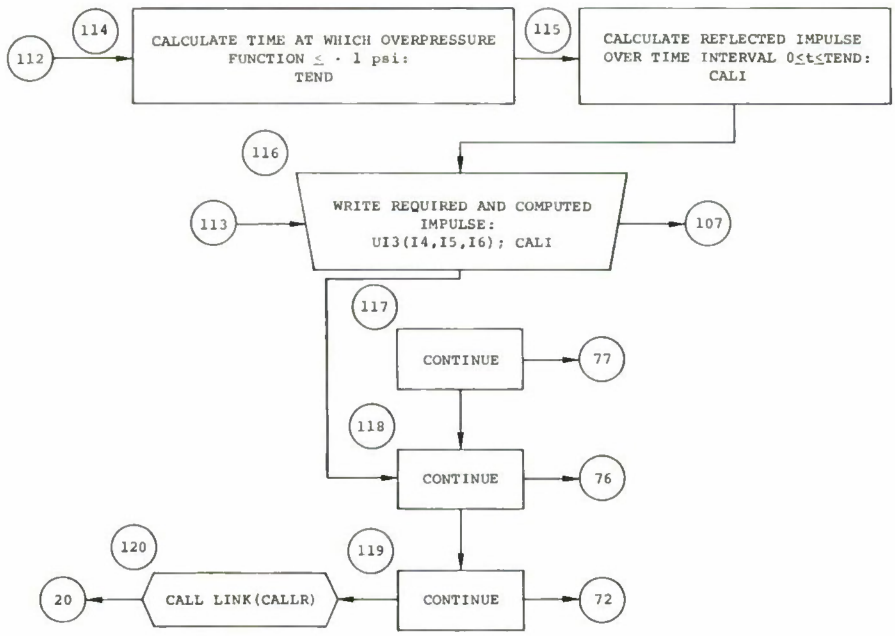


Figure 11 (Continued)



IV. CHURCH BUILDING ANALYSIS SUBROUTINE - CHURCH

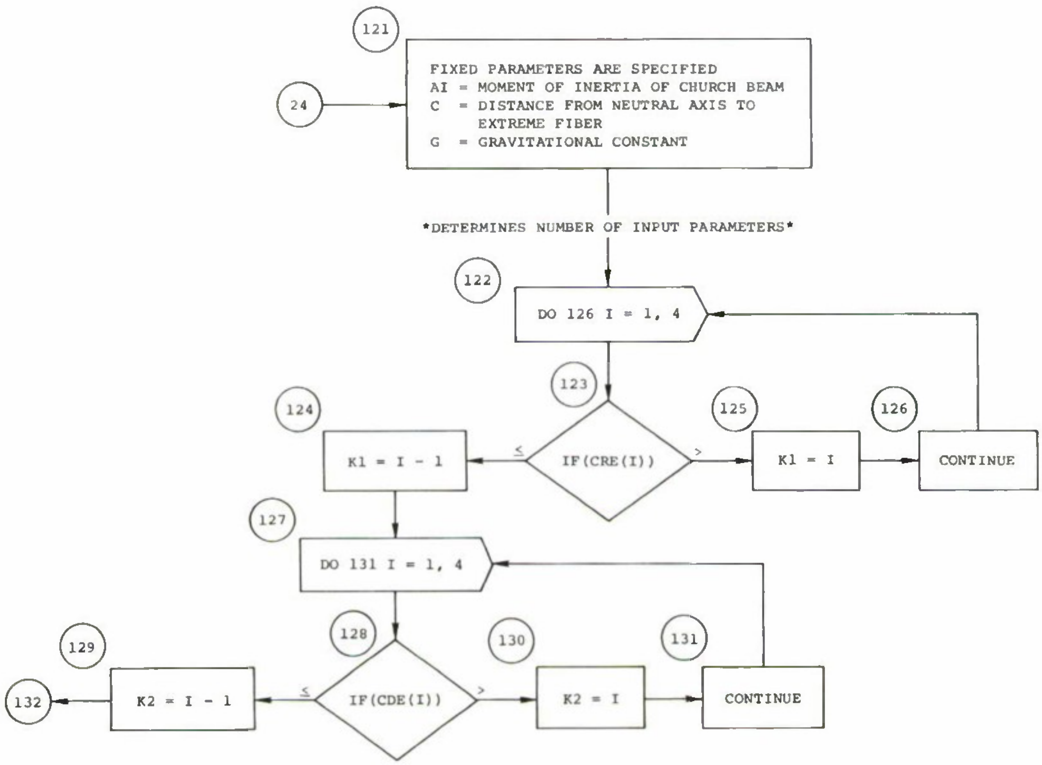
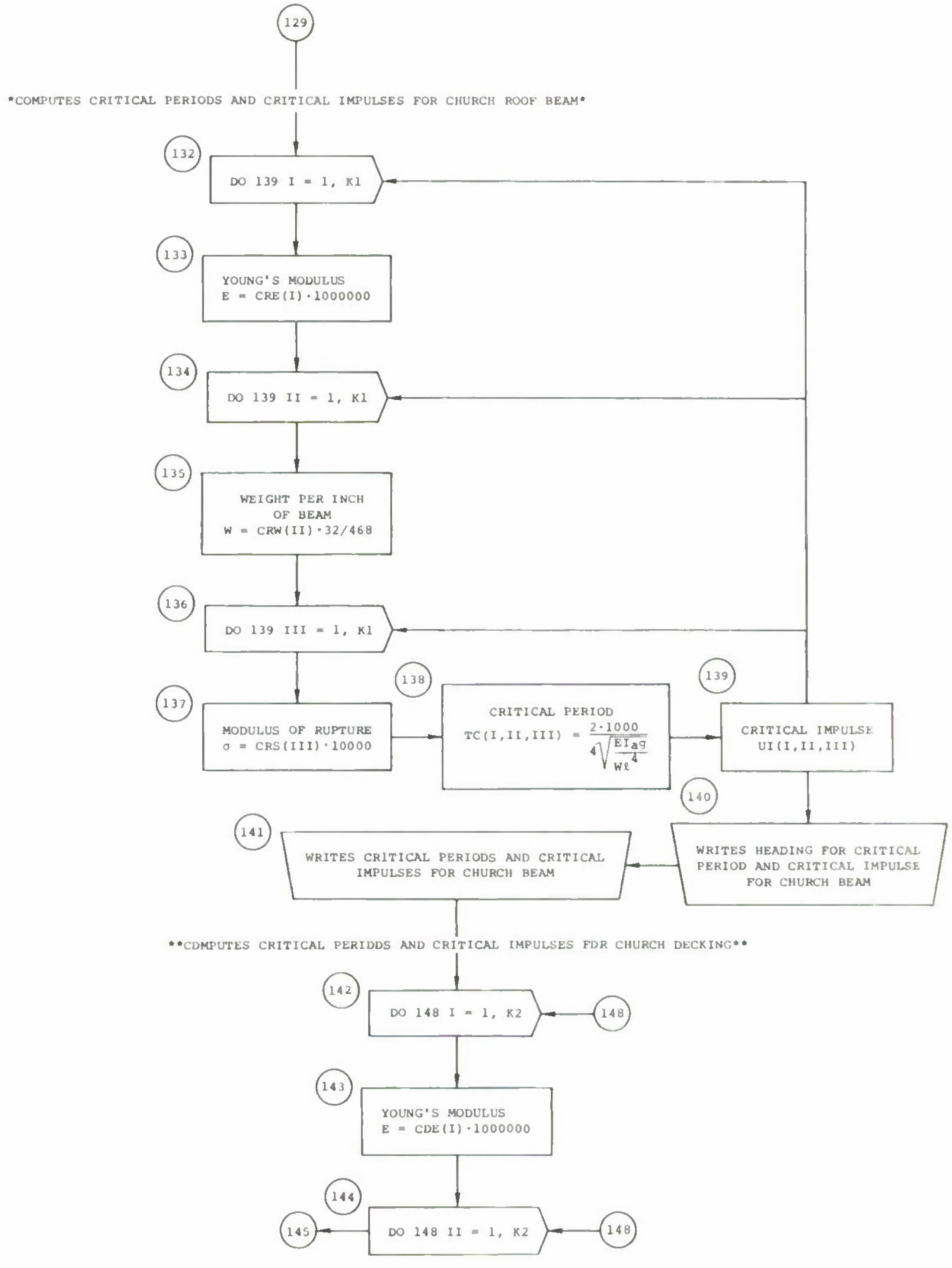


Figure 11 (Continued)



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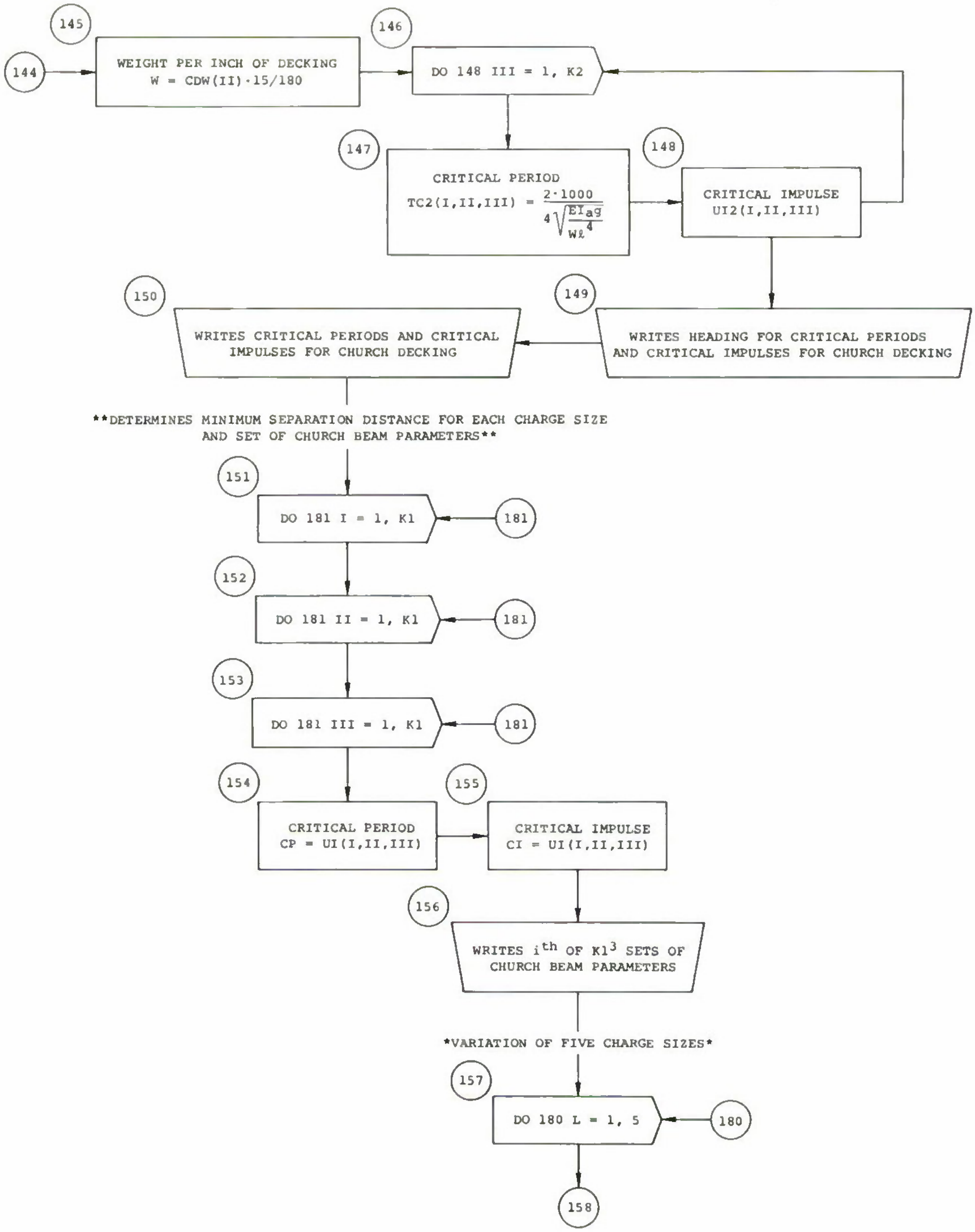

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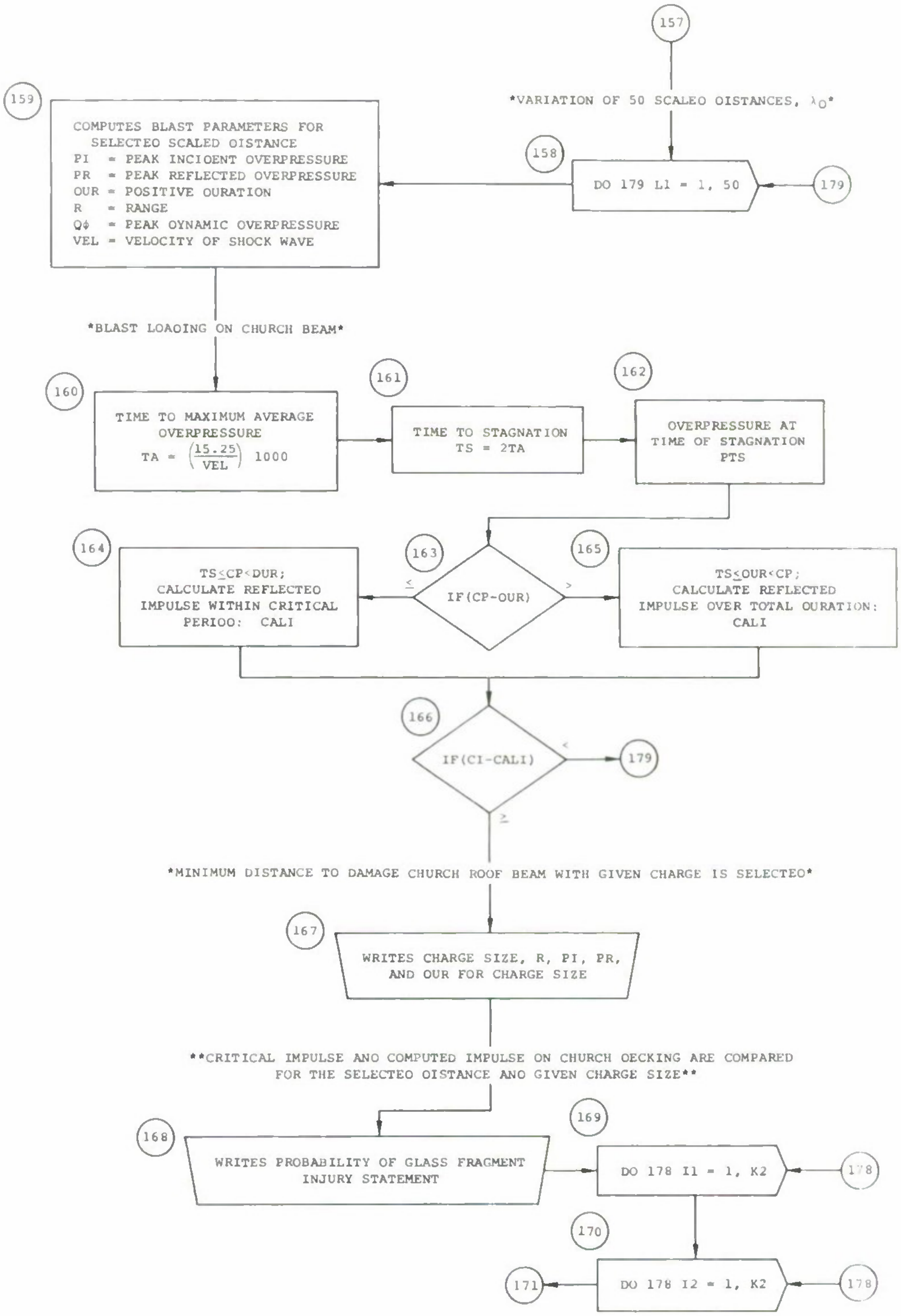

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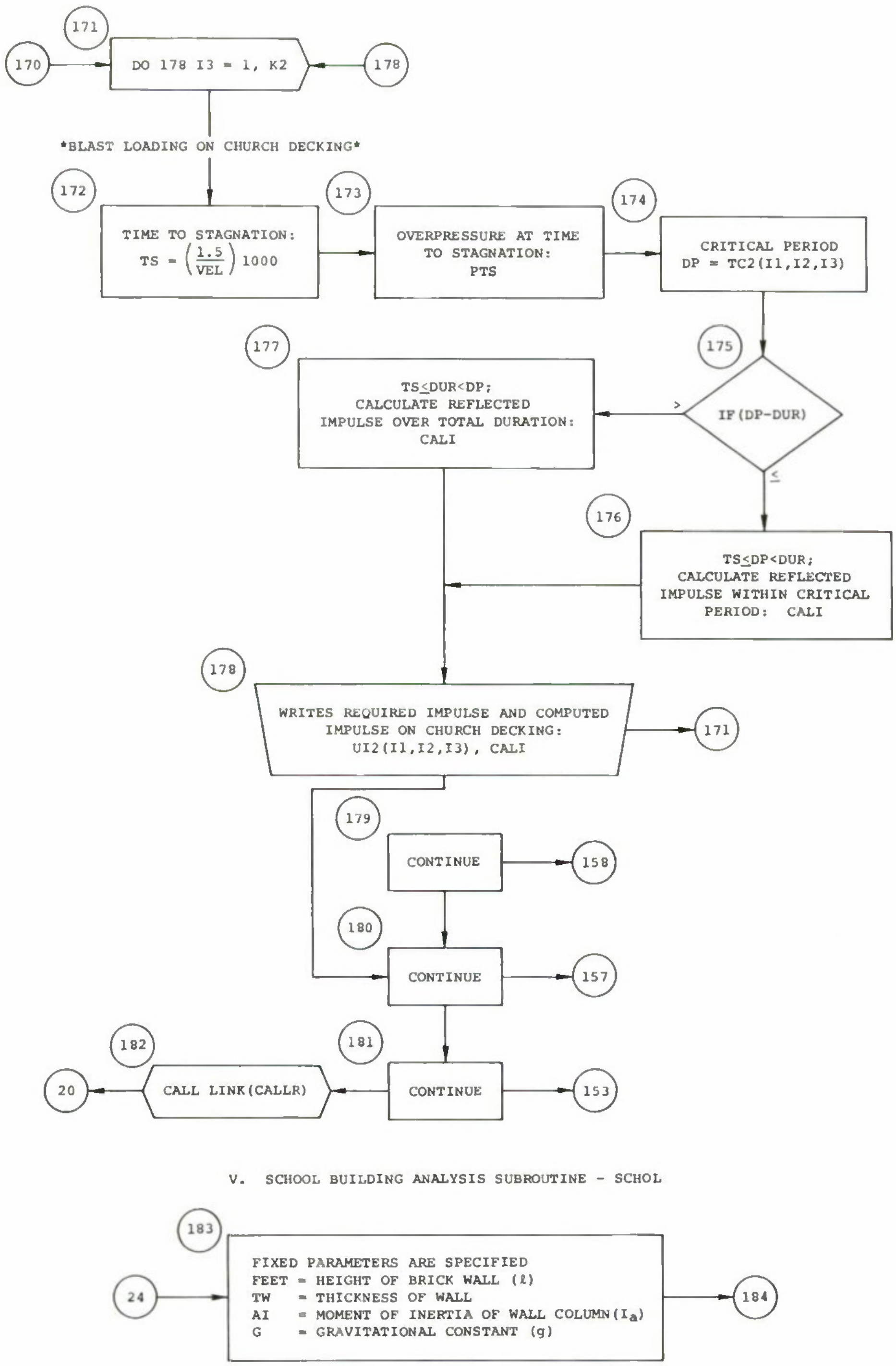

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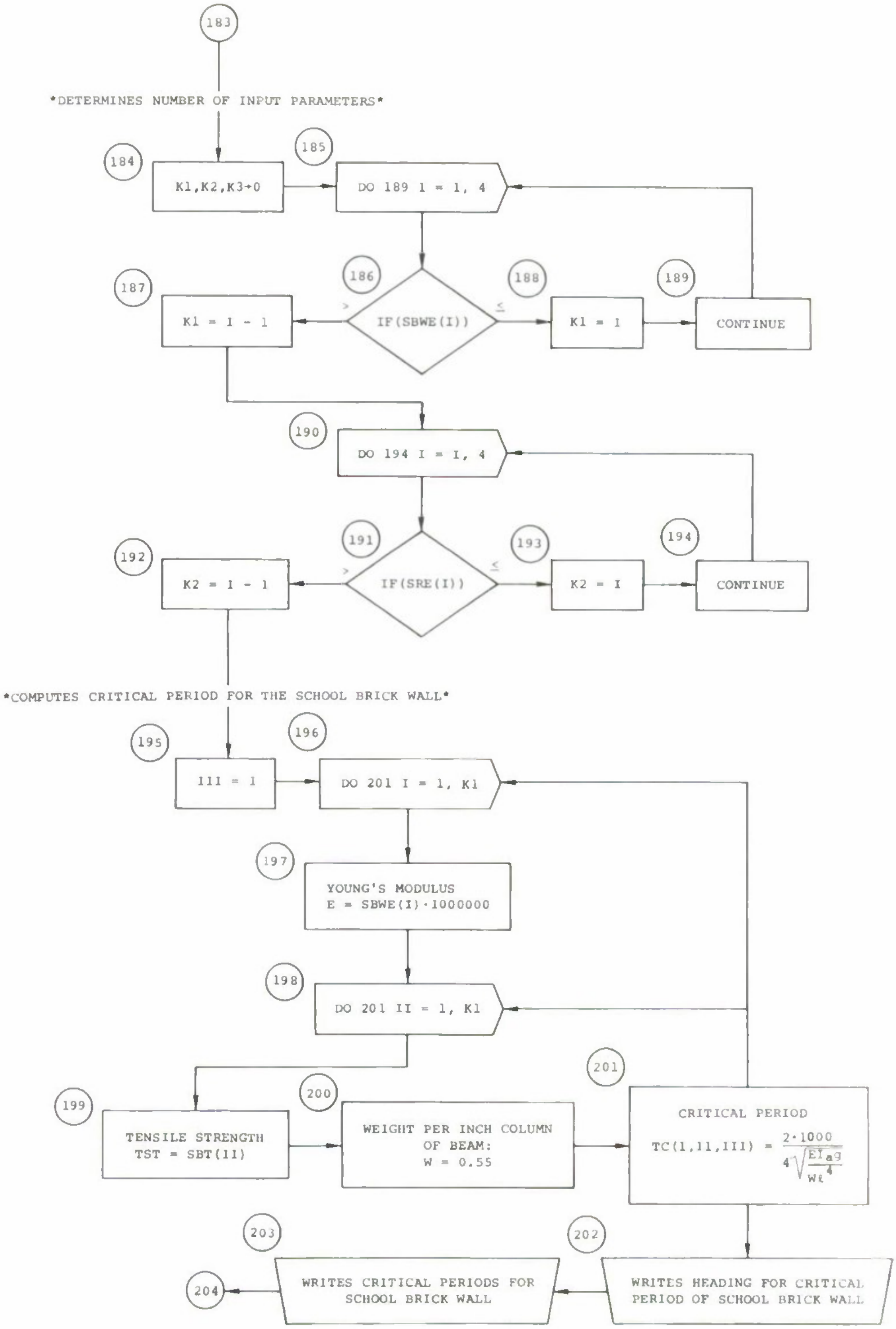

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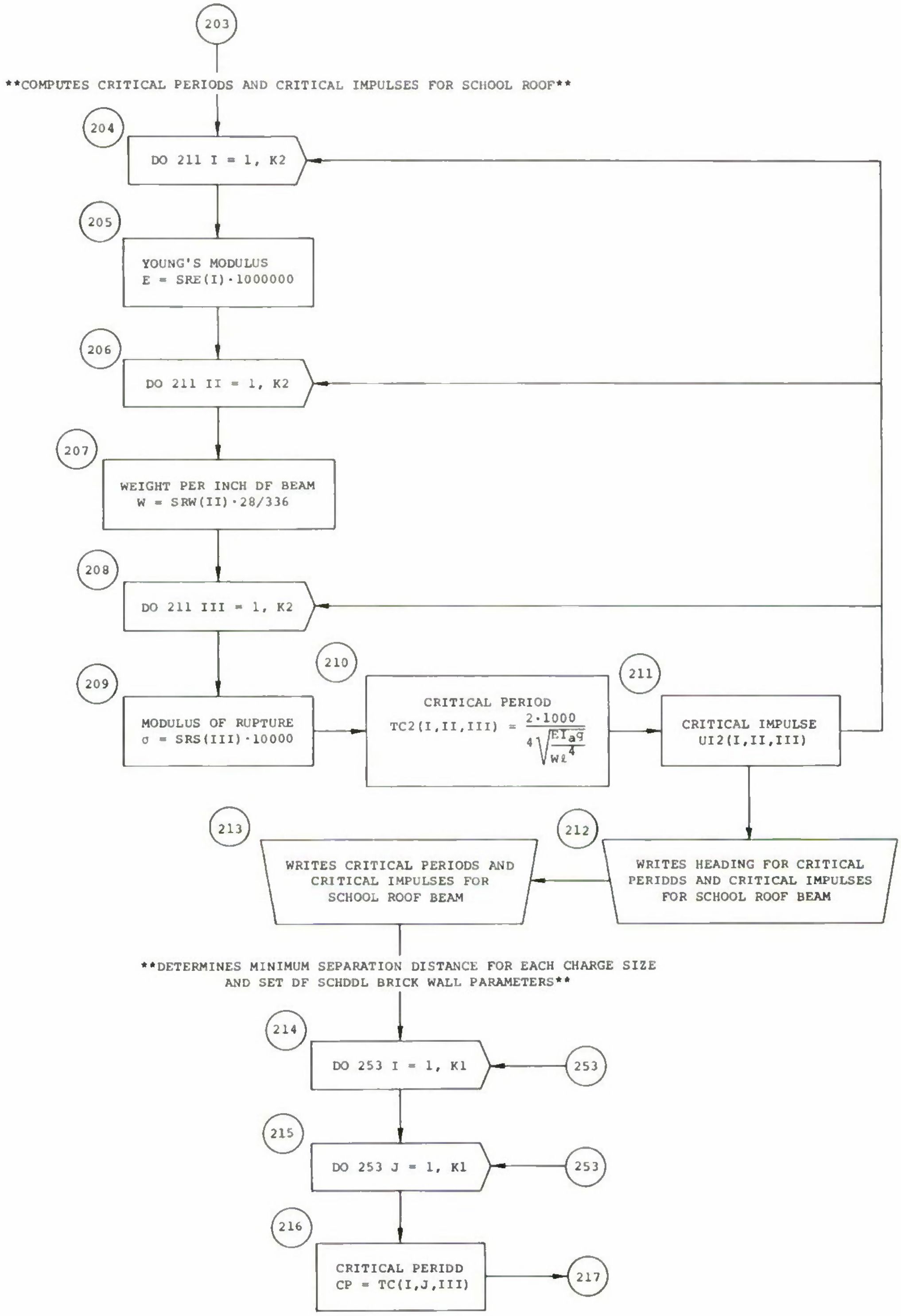

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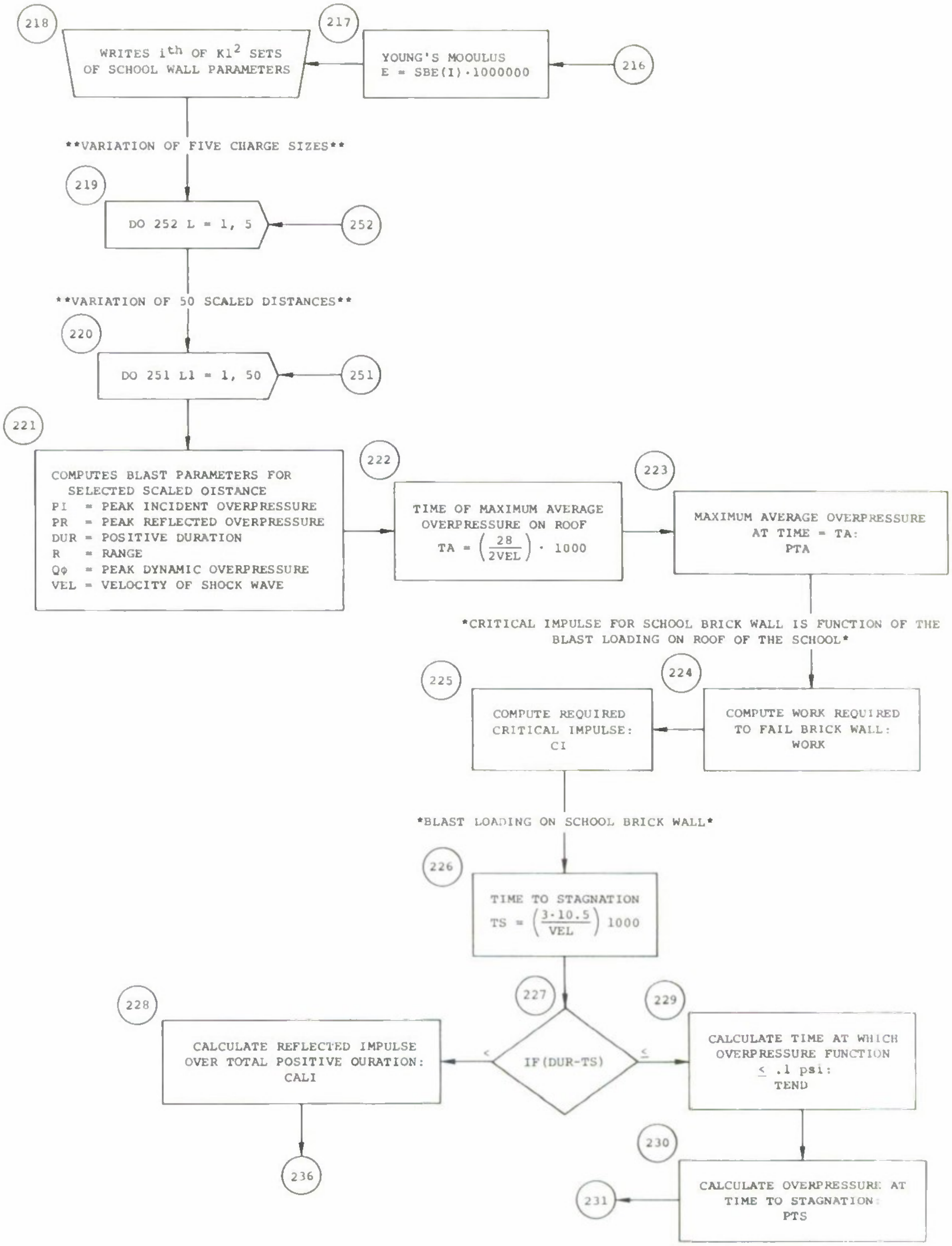


Figure 11 (Continued)

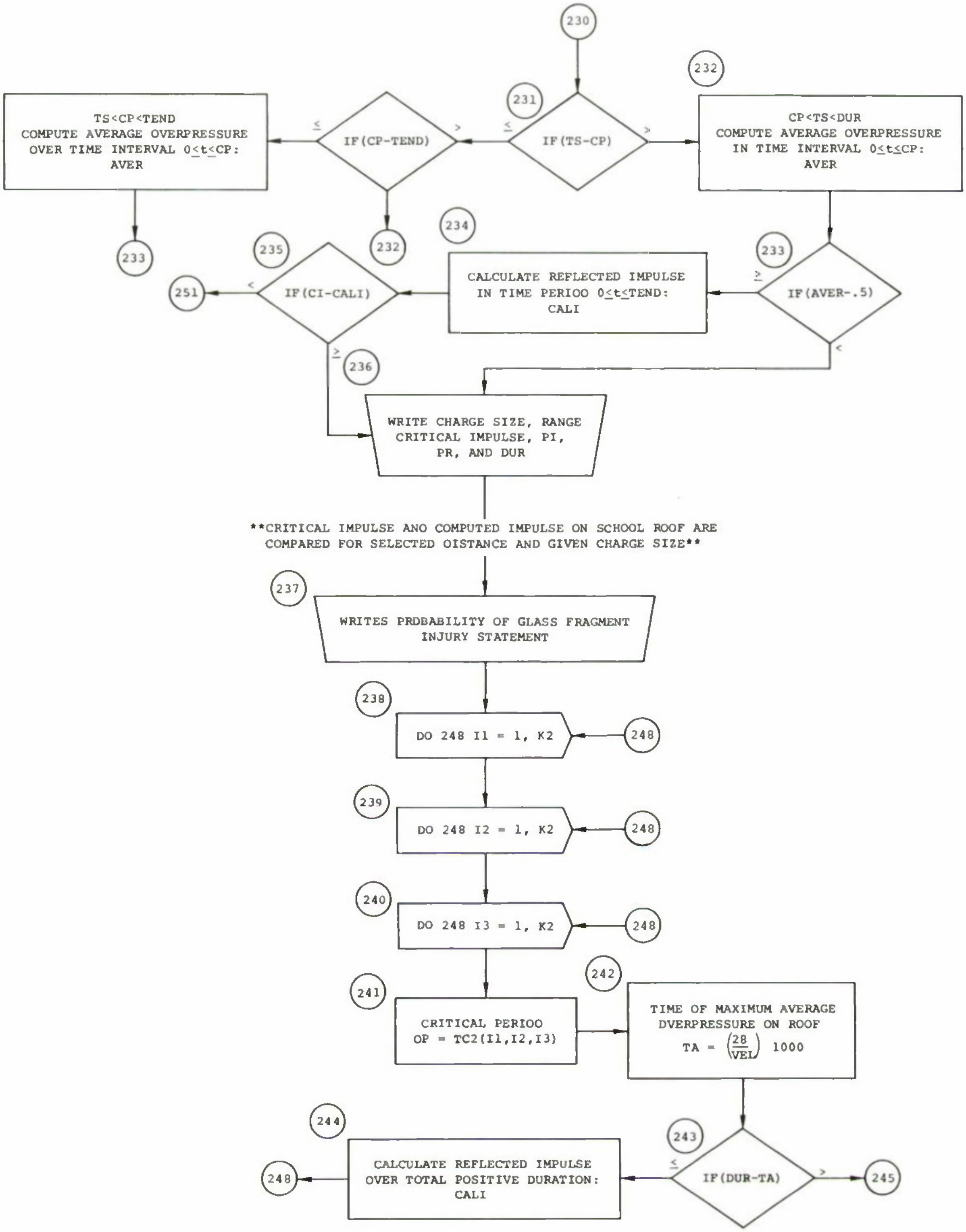
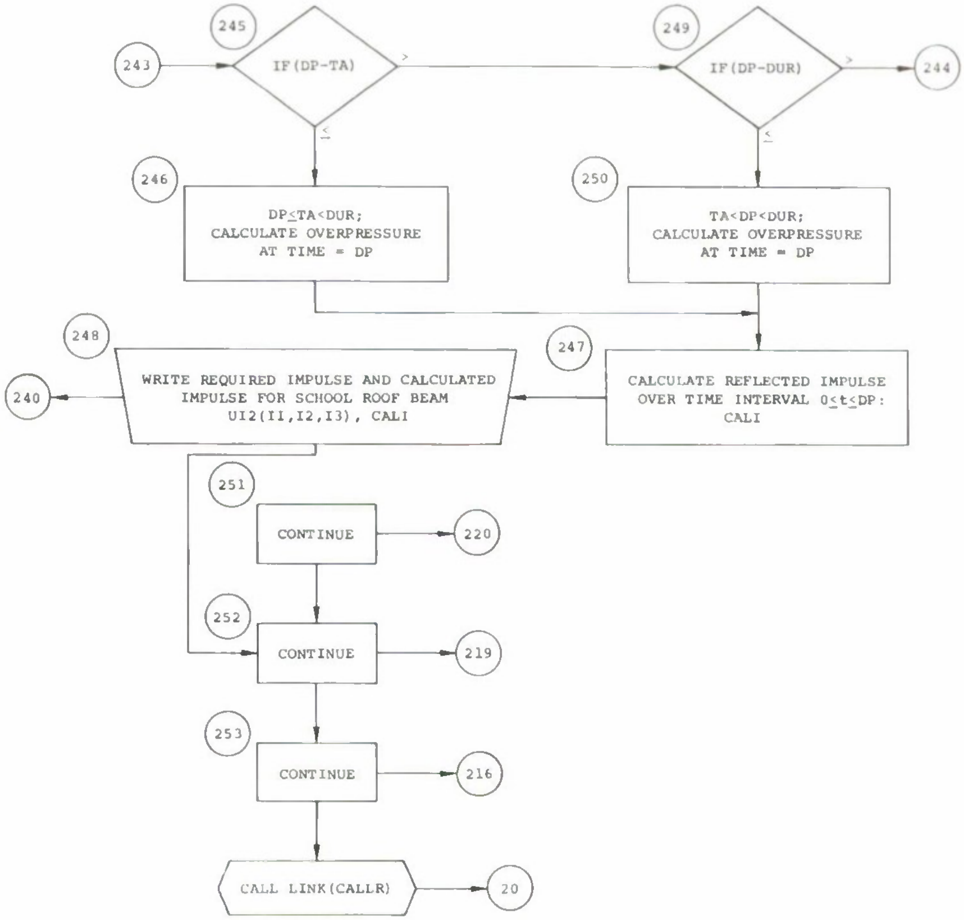
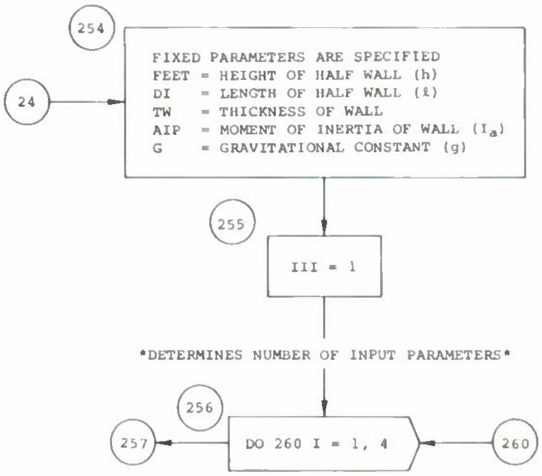


Figure 11 (Continued)



VI. OFFICE BUILDING (HALF WALL WITH WINDOWS) ANALYSIS SUBROUTINE - OHAFW



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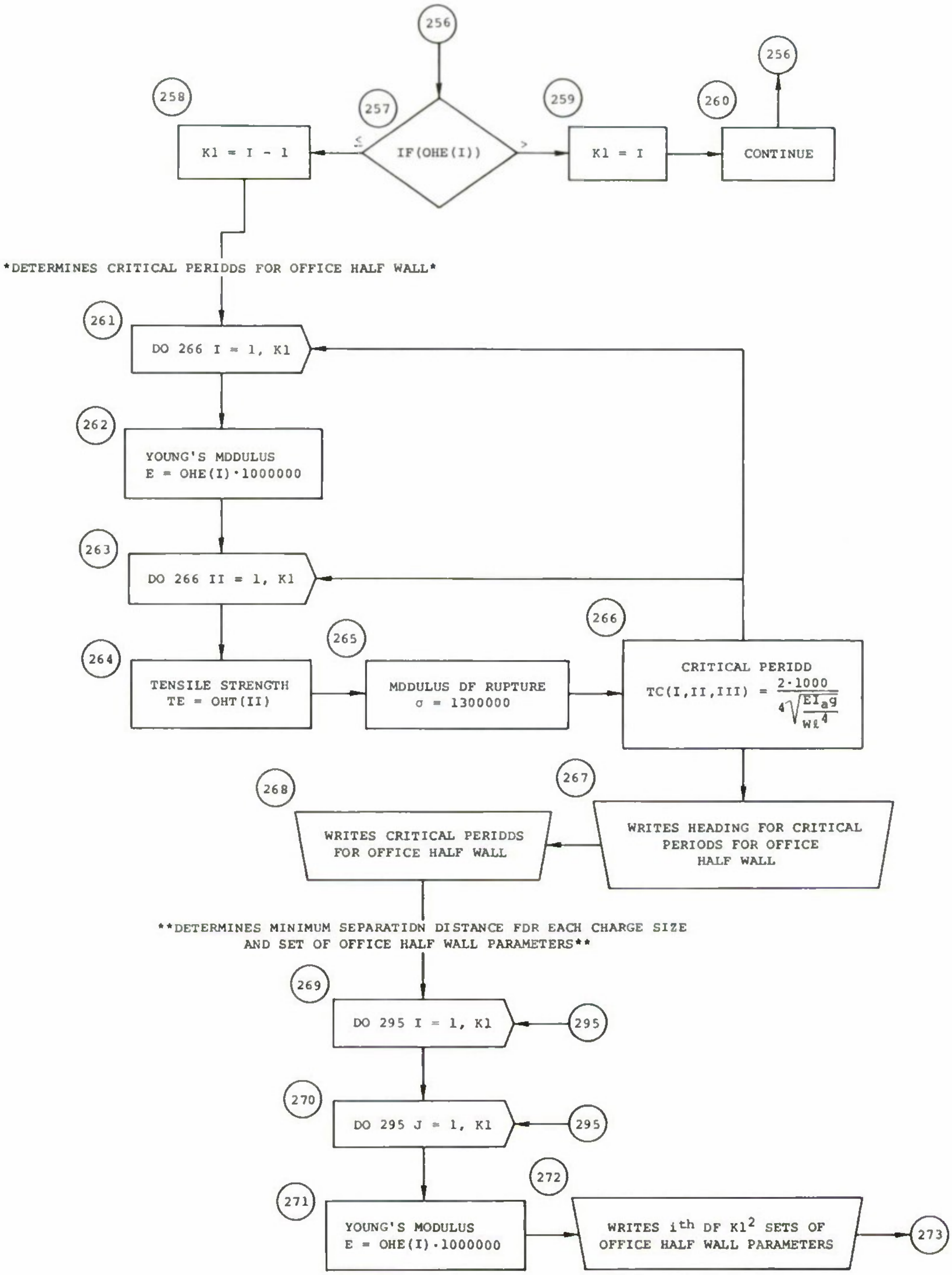

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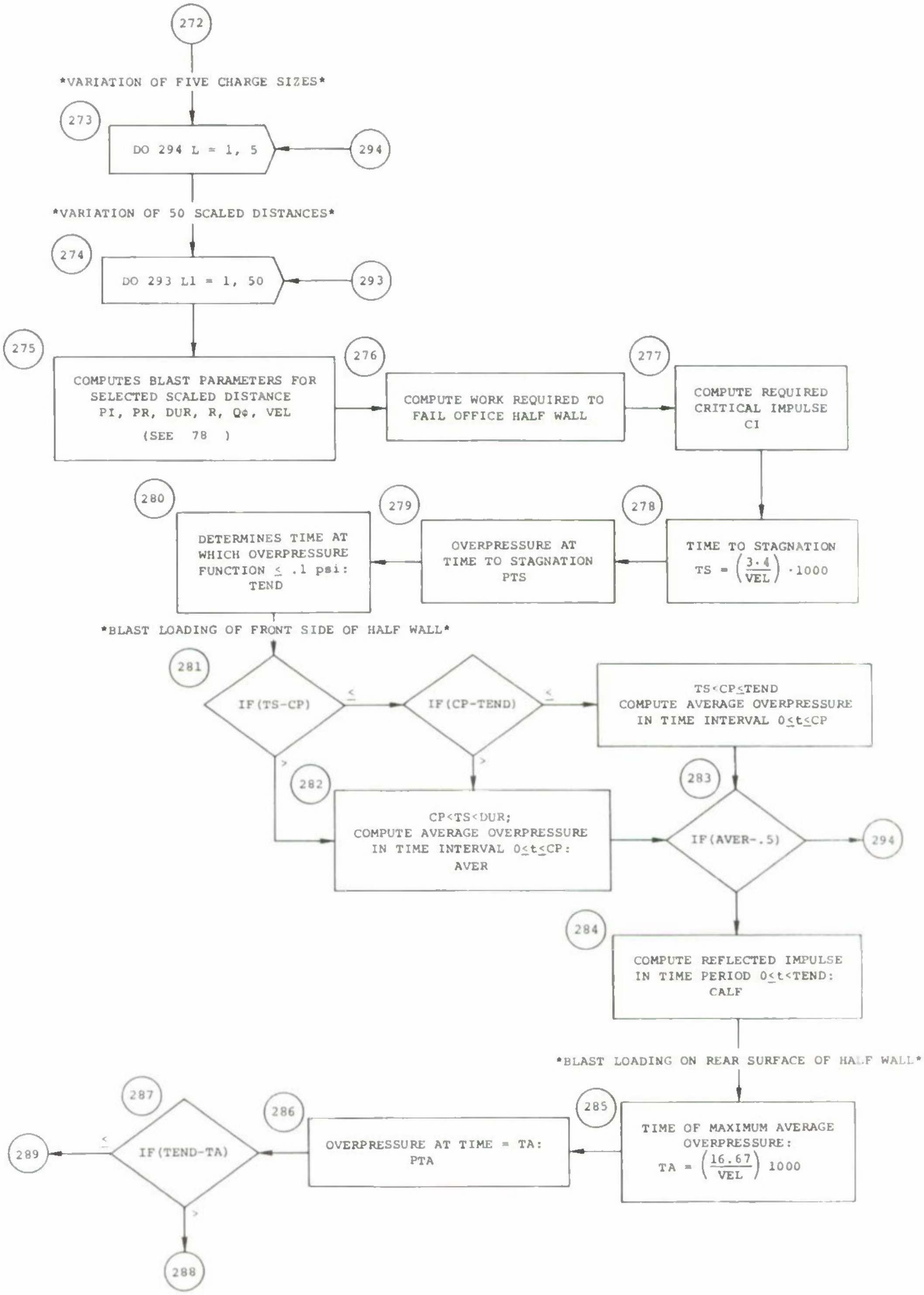

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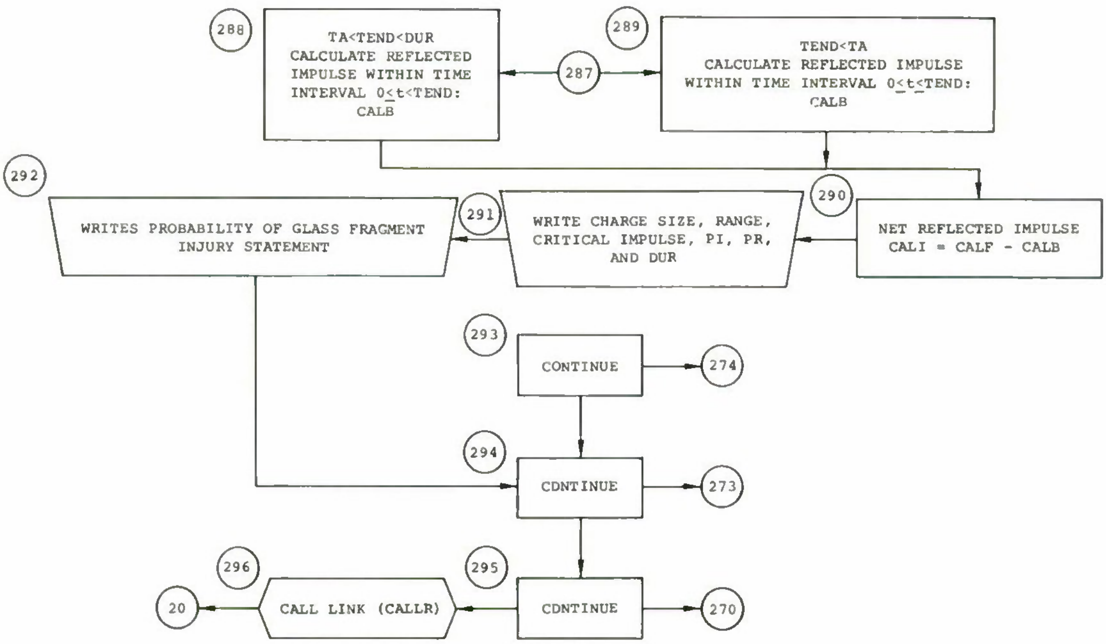
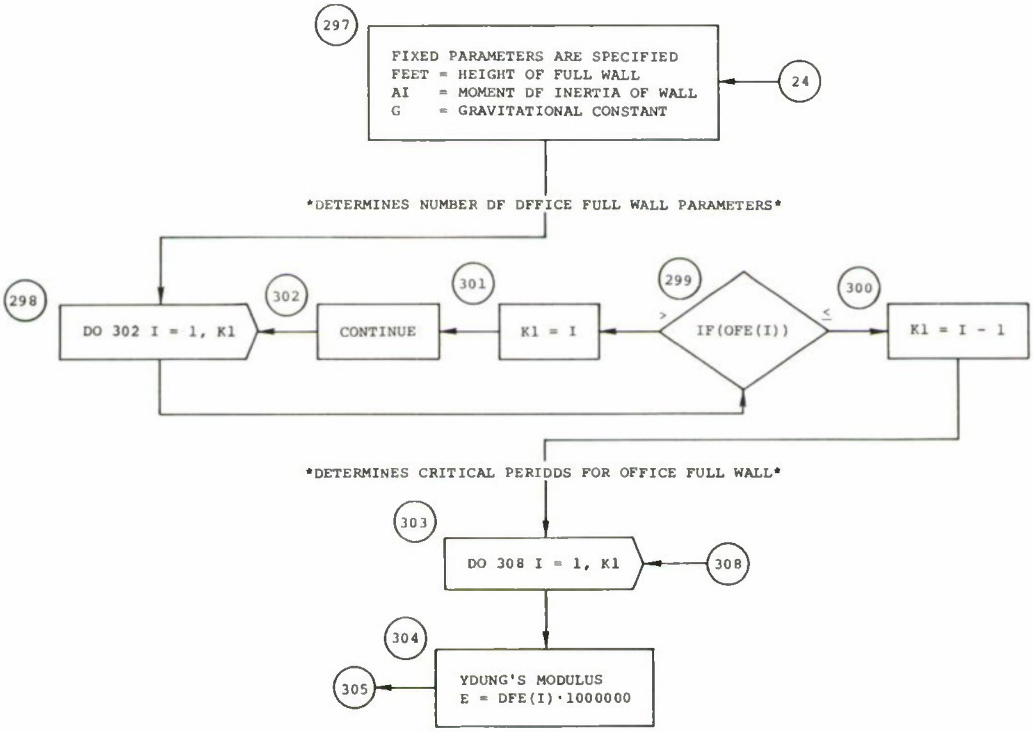


VII. OFFICE BUILDING (FULL WALL WITH NO OPENING) - OFFICE



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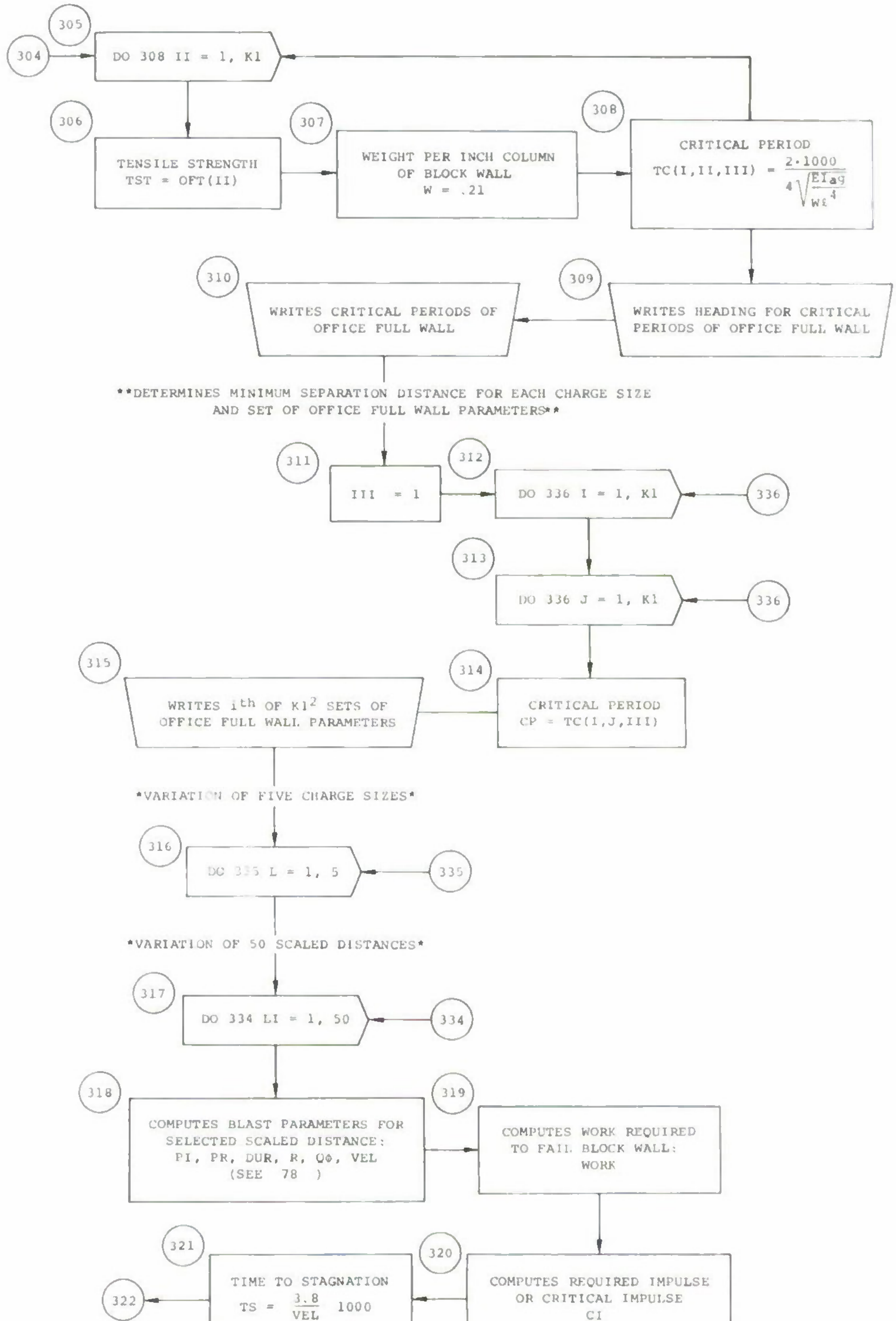

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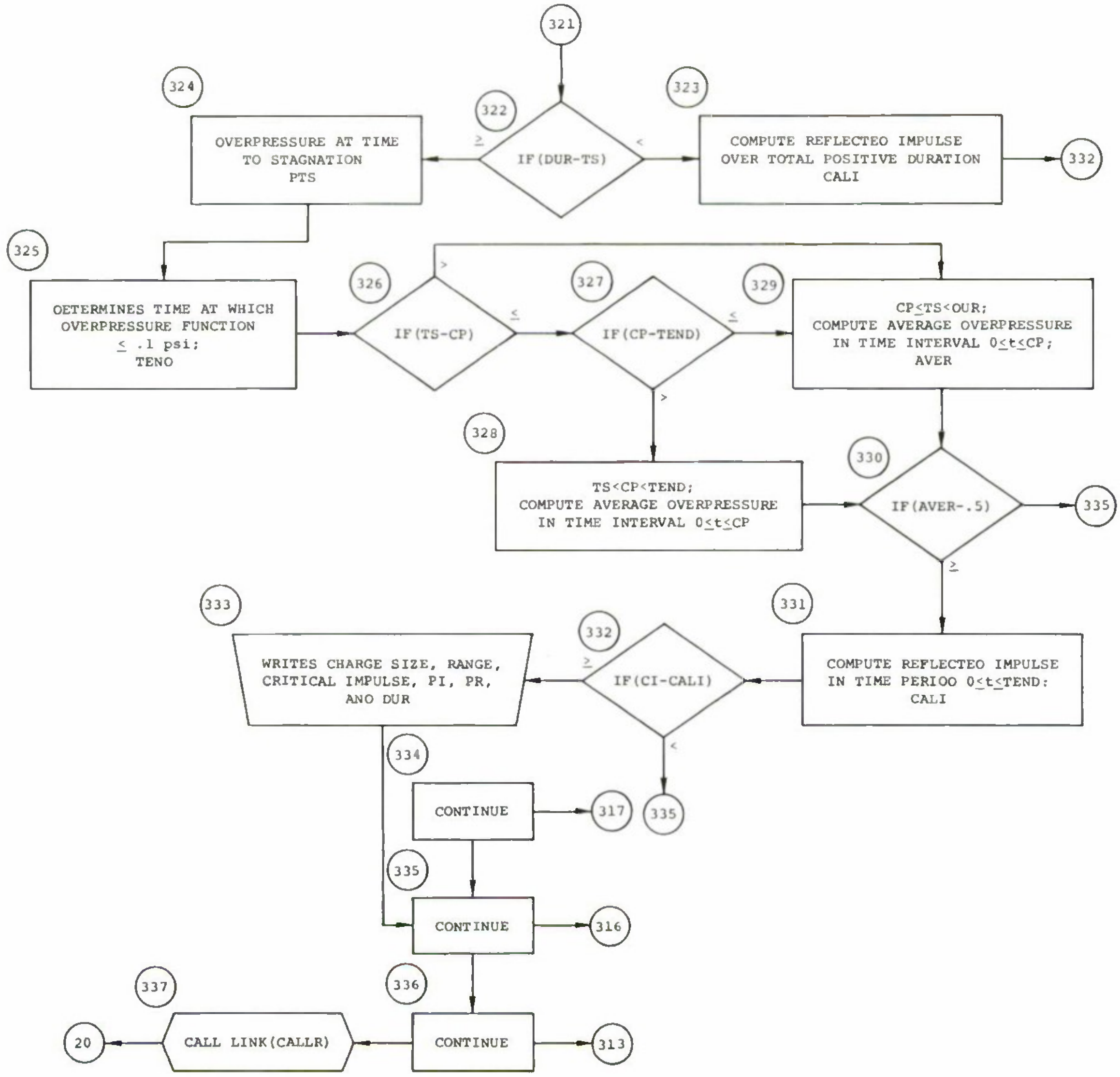
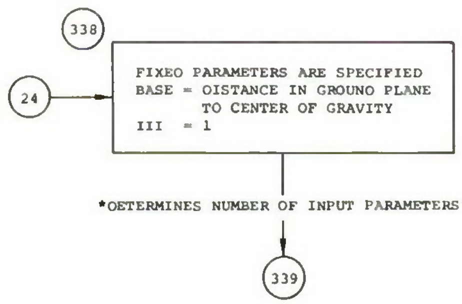


VIII. PASSENGER BUS OVERTURNING SUBROUTINE - BUS



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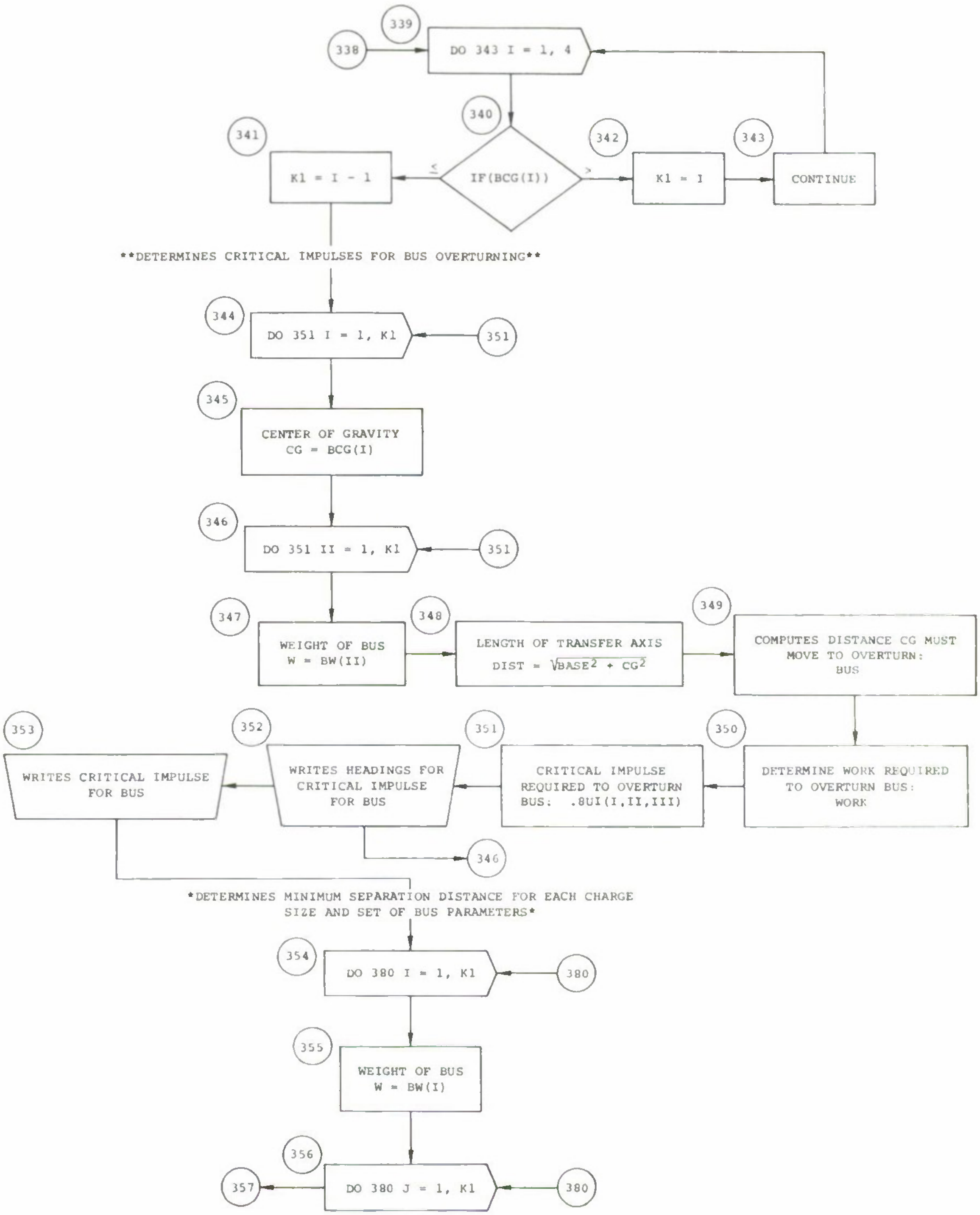

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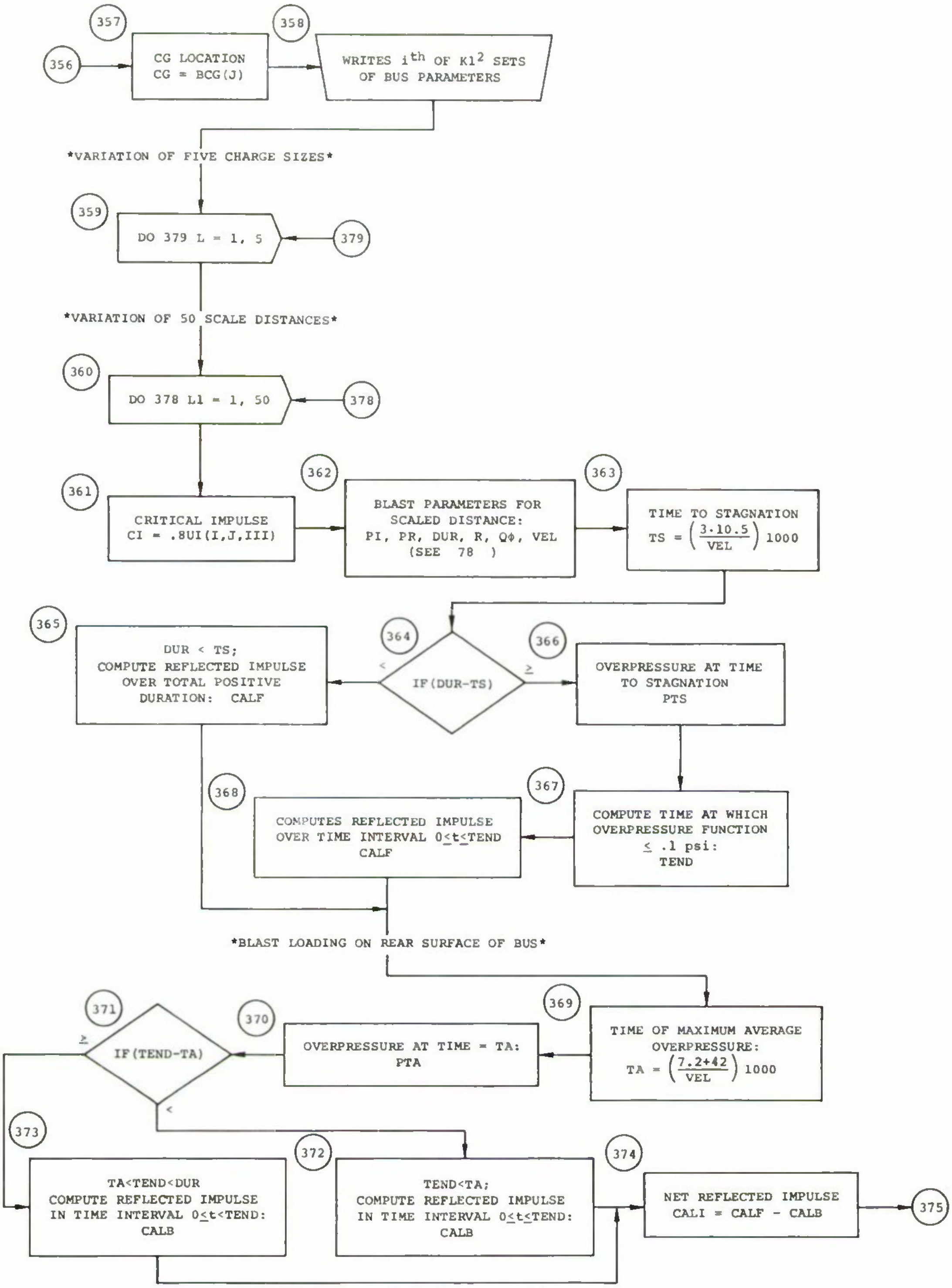

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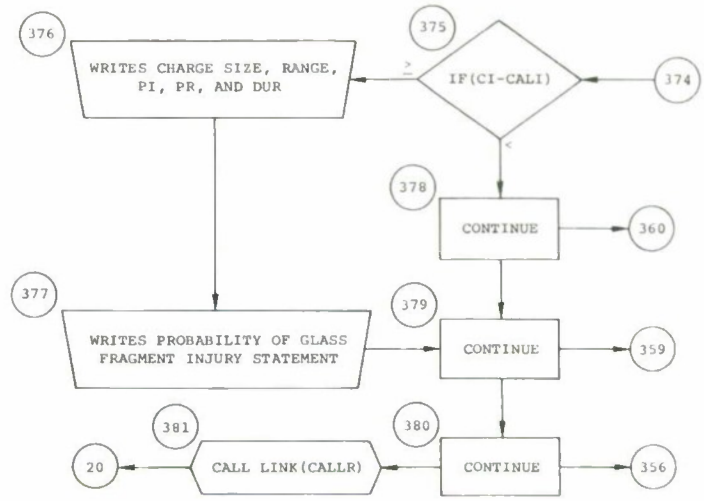
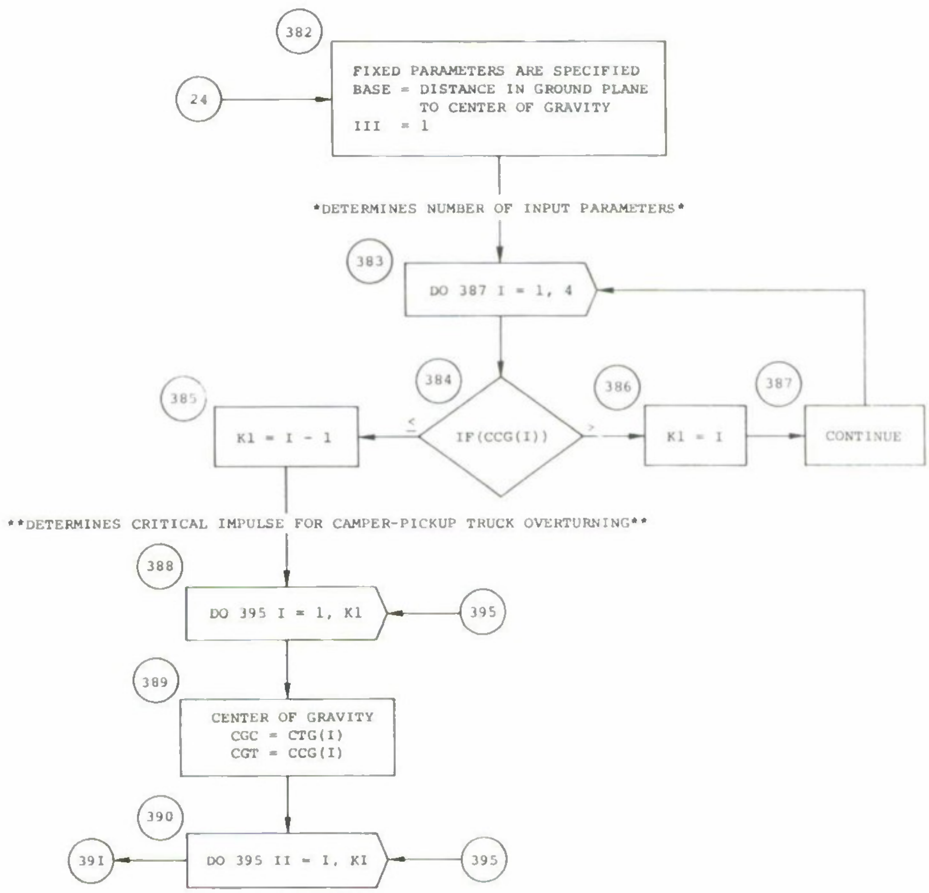


IX. CAMPER AND PICKUP TRUCK OVERTURNING SUBROUTINE - CAMPR



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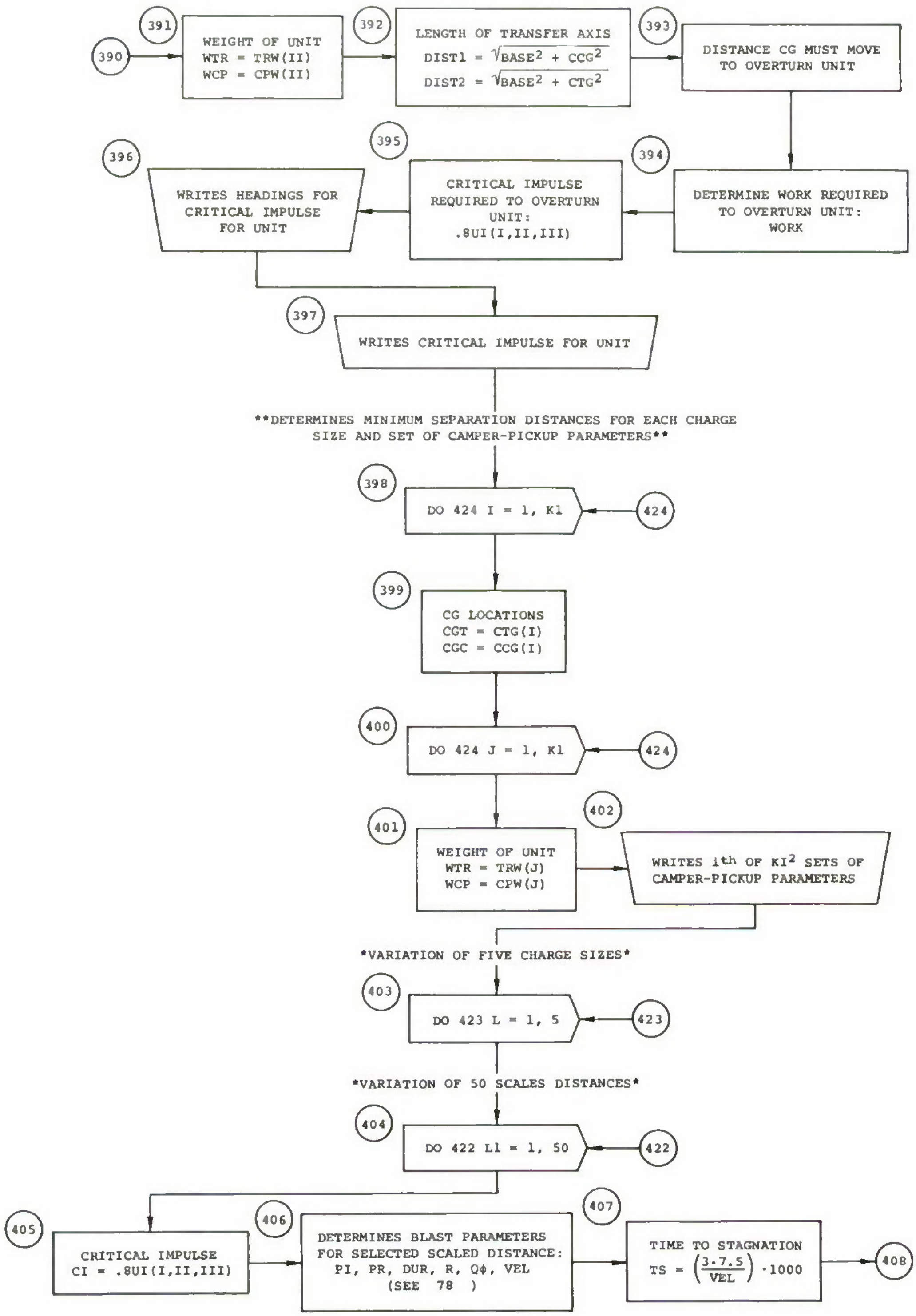

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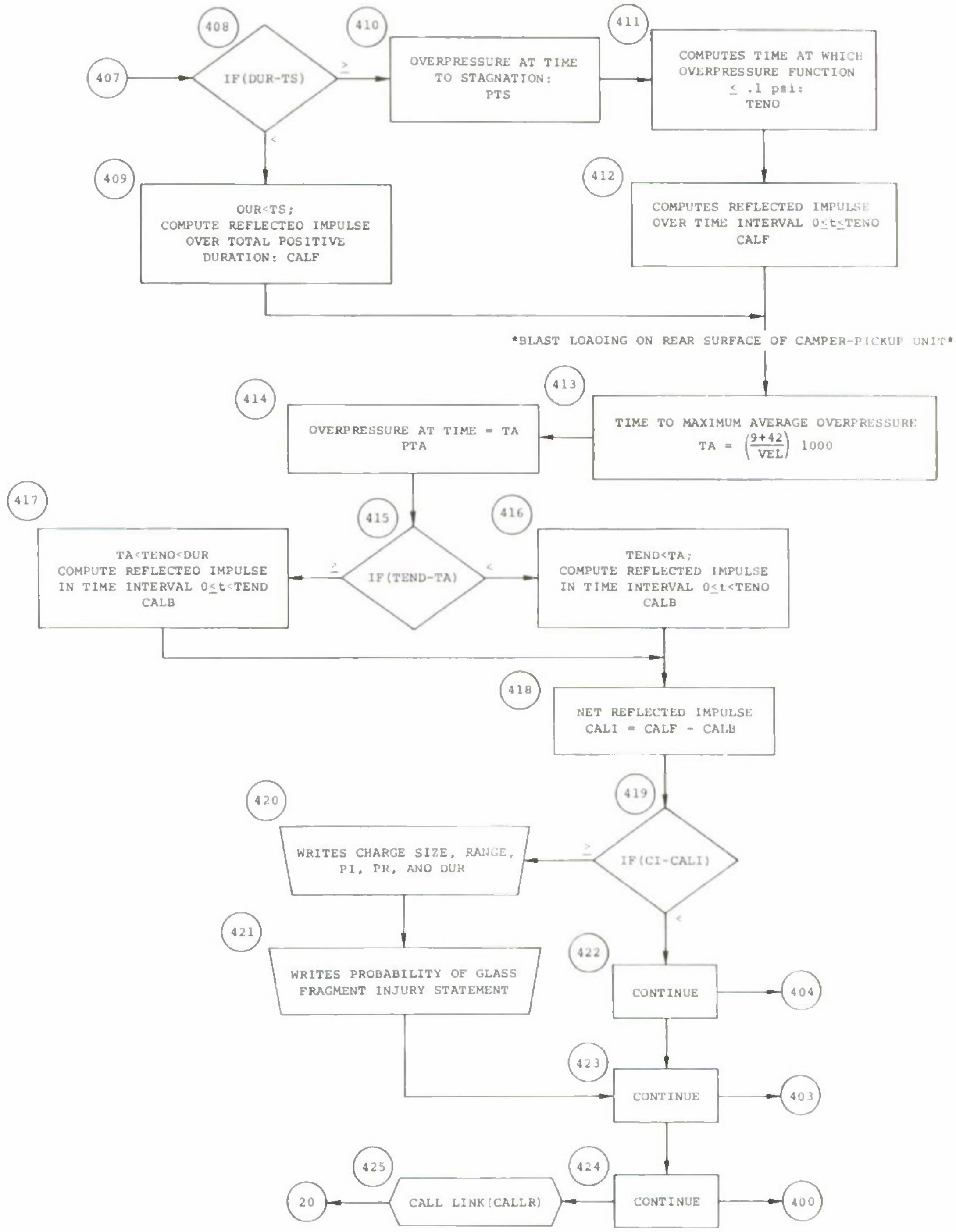

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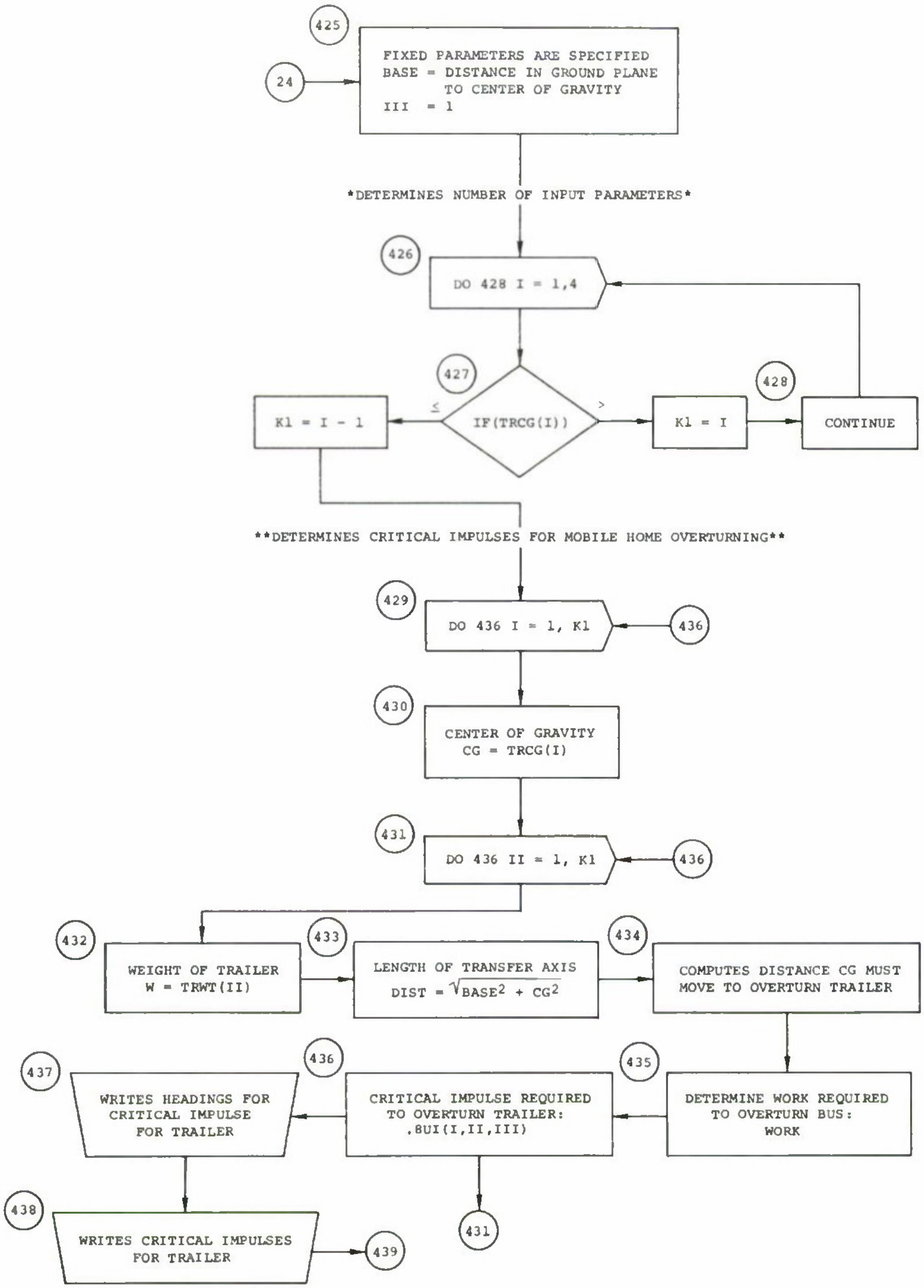
X. MOBILE HOME OVERTURNING SUBROUTINE - TRLER



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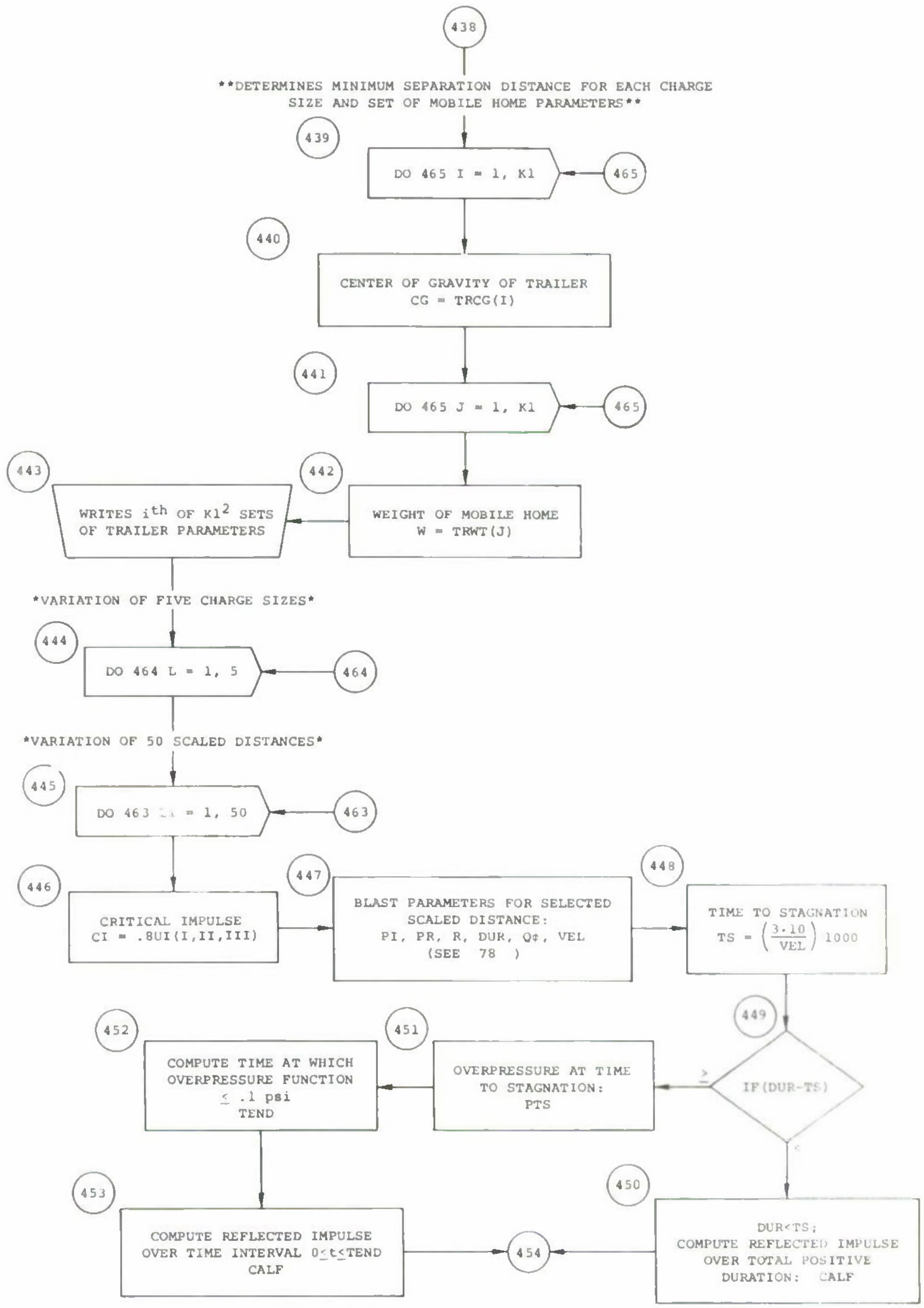

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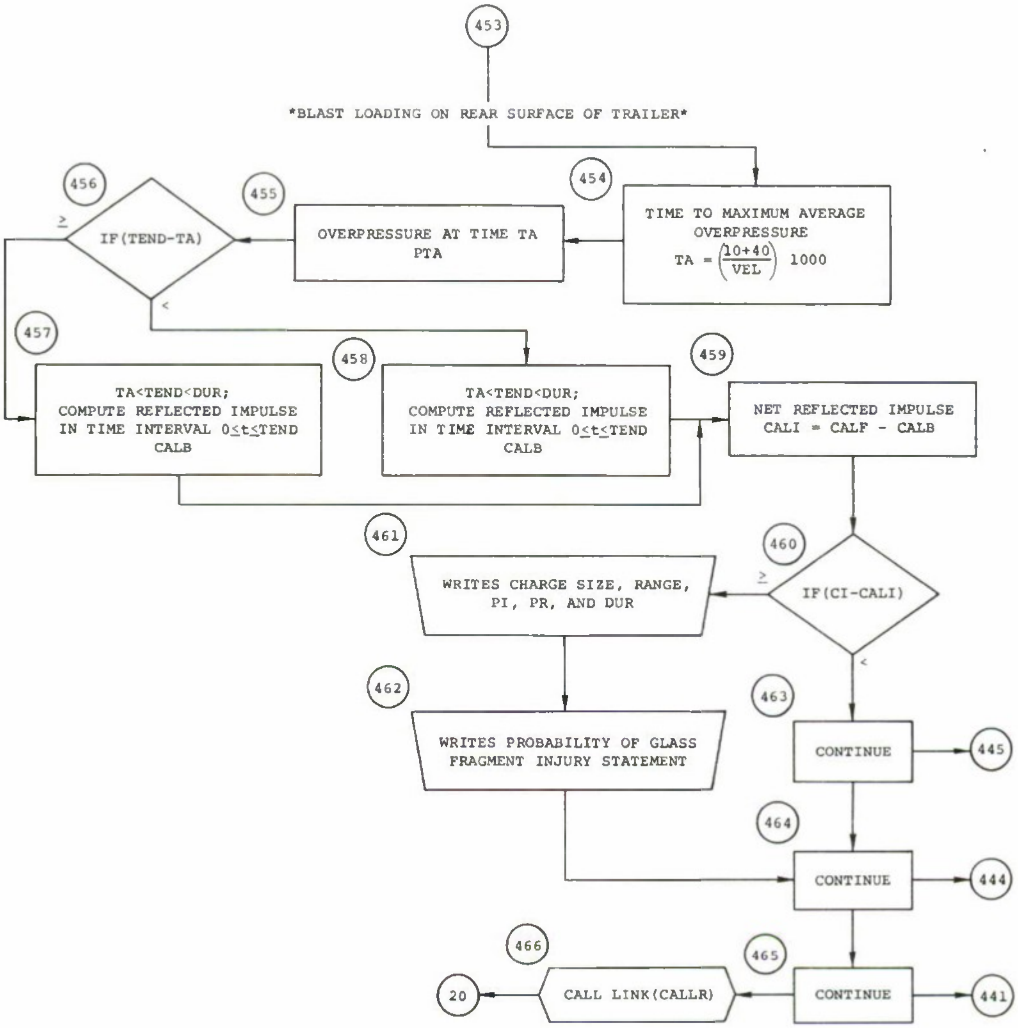
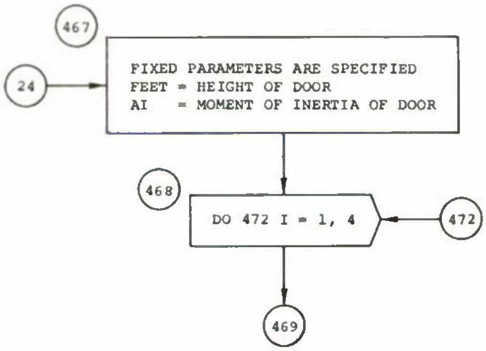


XI. IGLOO DOOR ANALYSIS SUBROUTINE - DOOR



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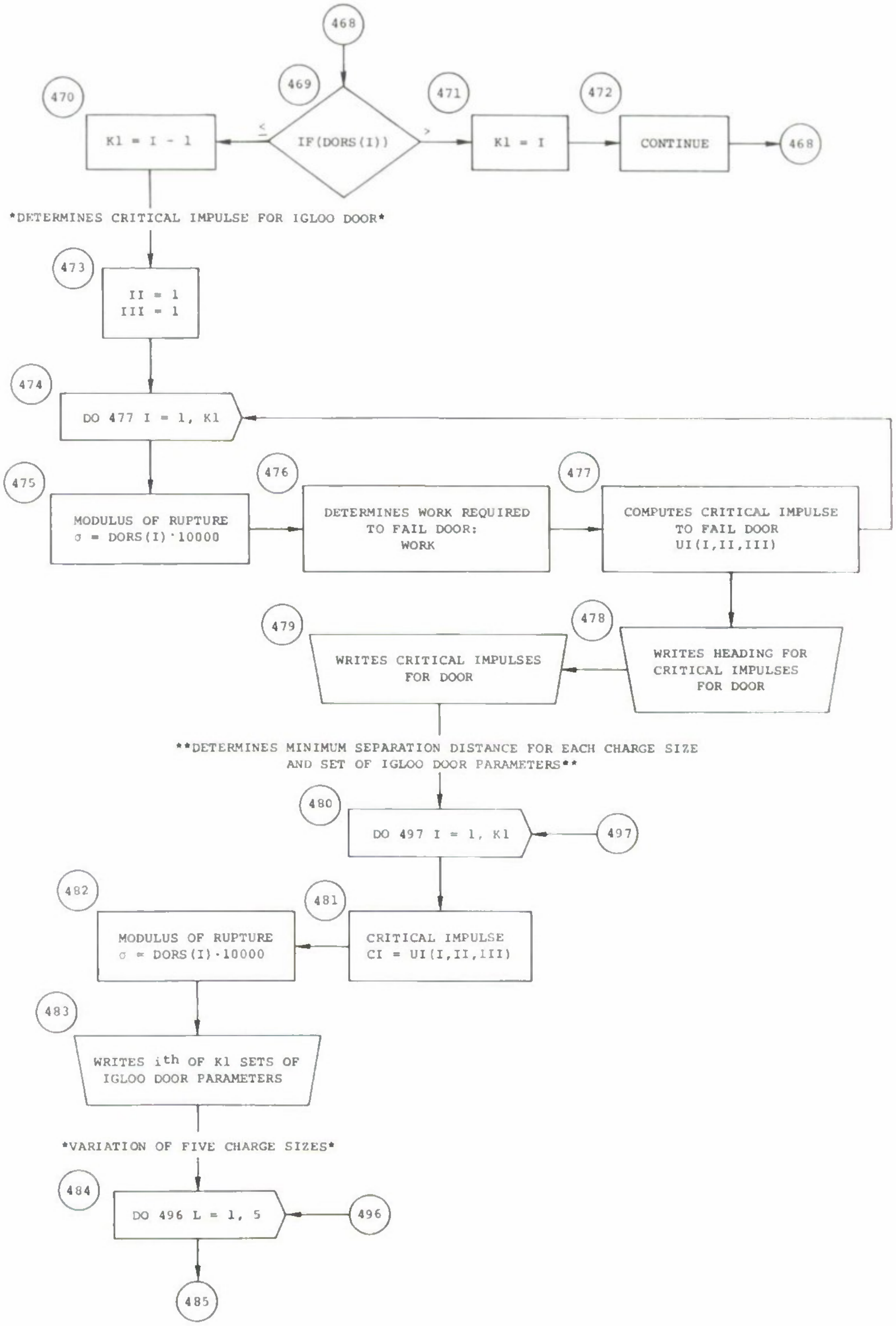

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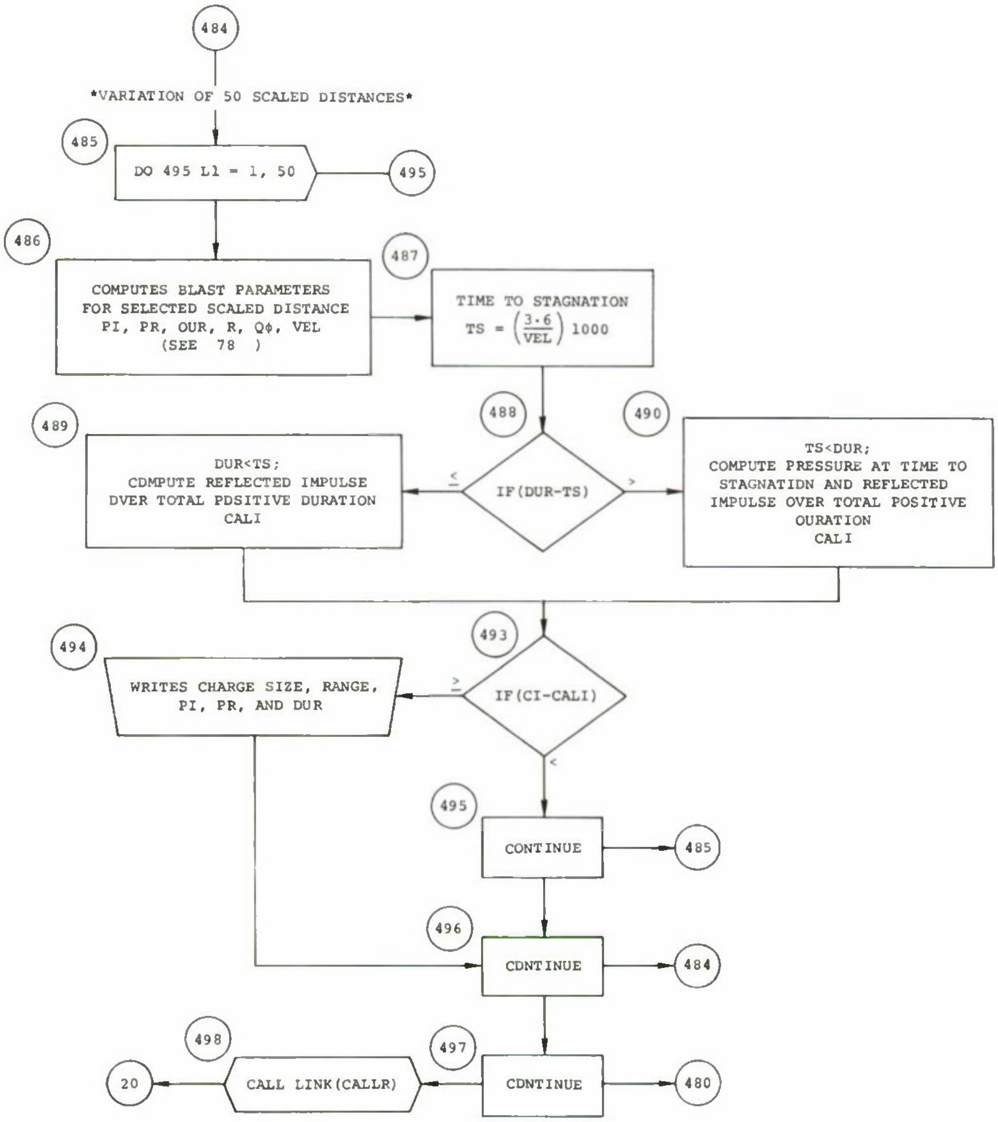
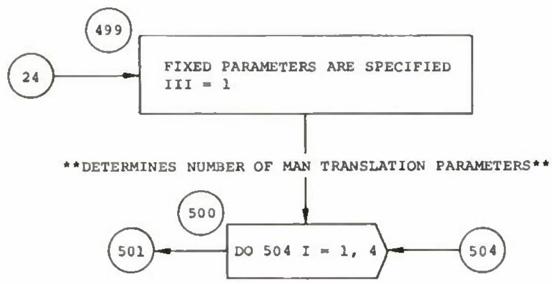


XII. MAN TRANSLATION SUBROUTINE - MAN



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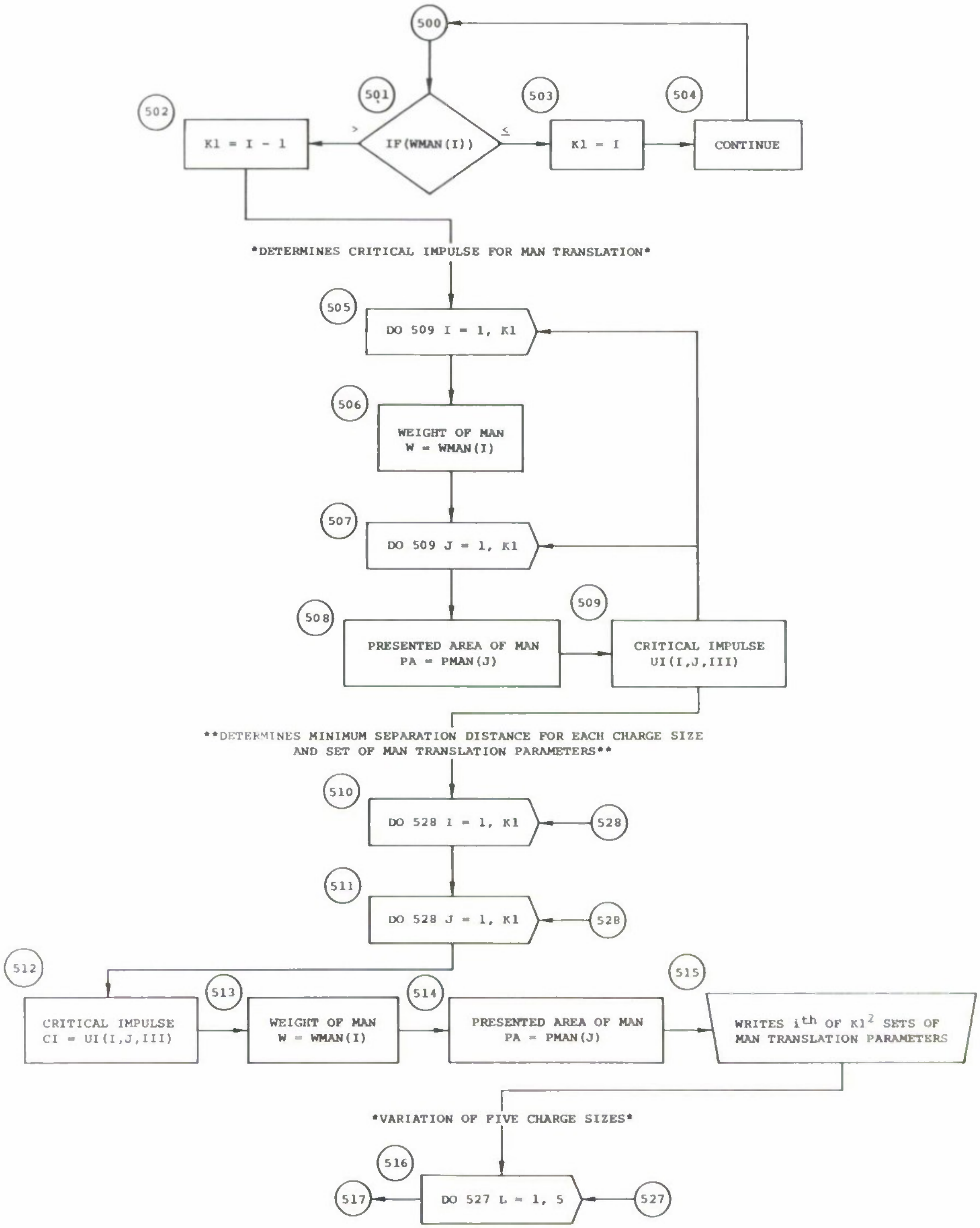

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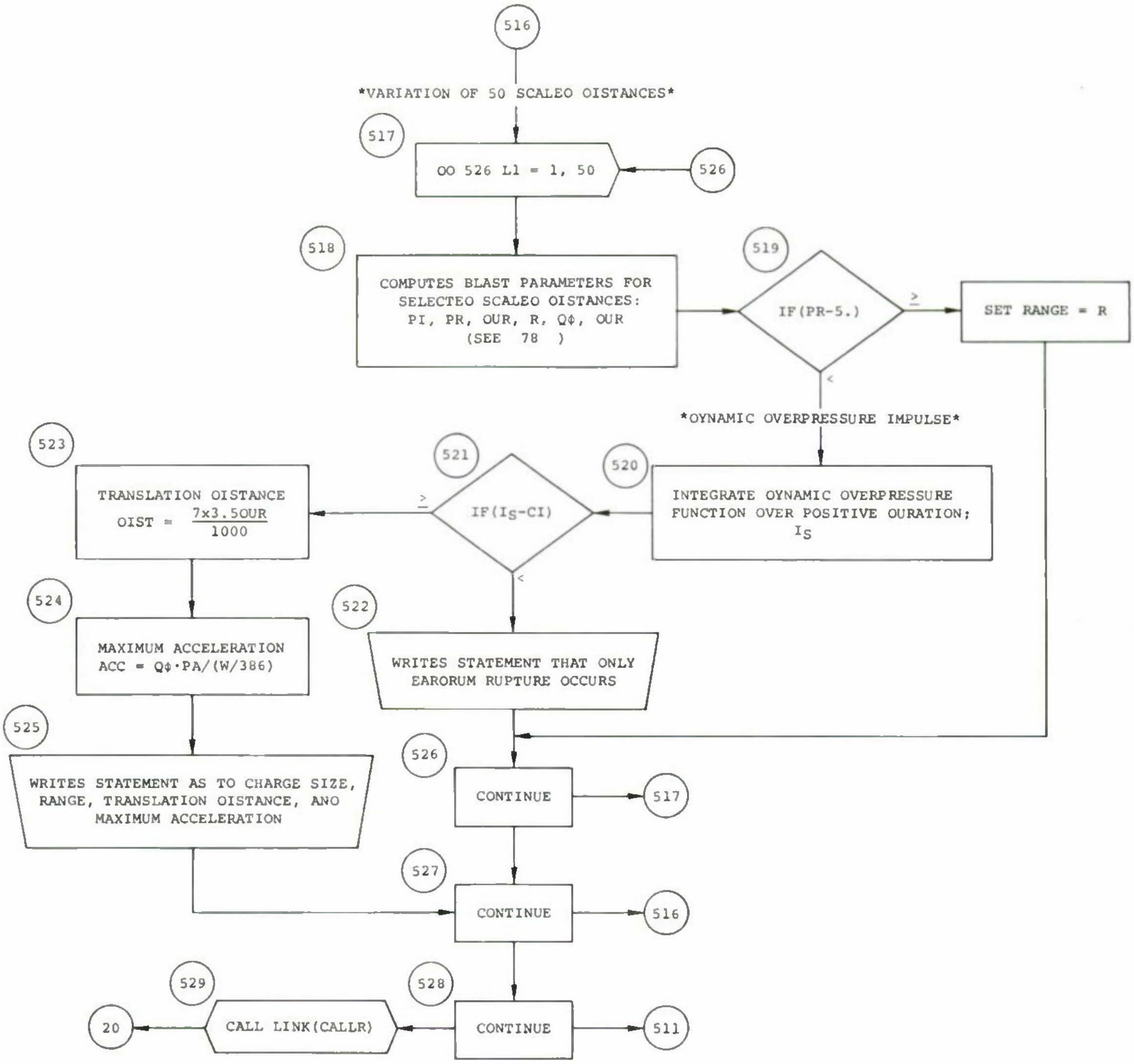
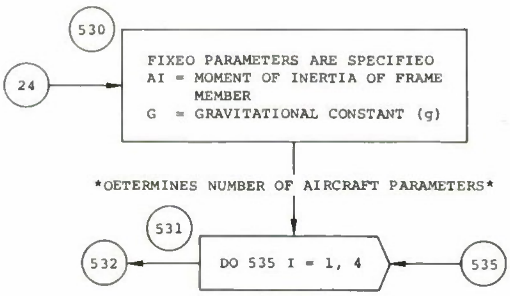


XIII. COMMERCIAL JET AIRCRAFT ANALYSIS SUBROUTINE - AIRP



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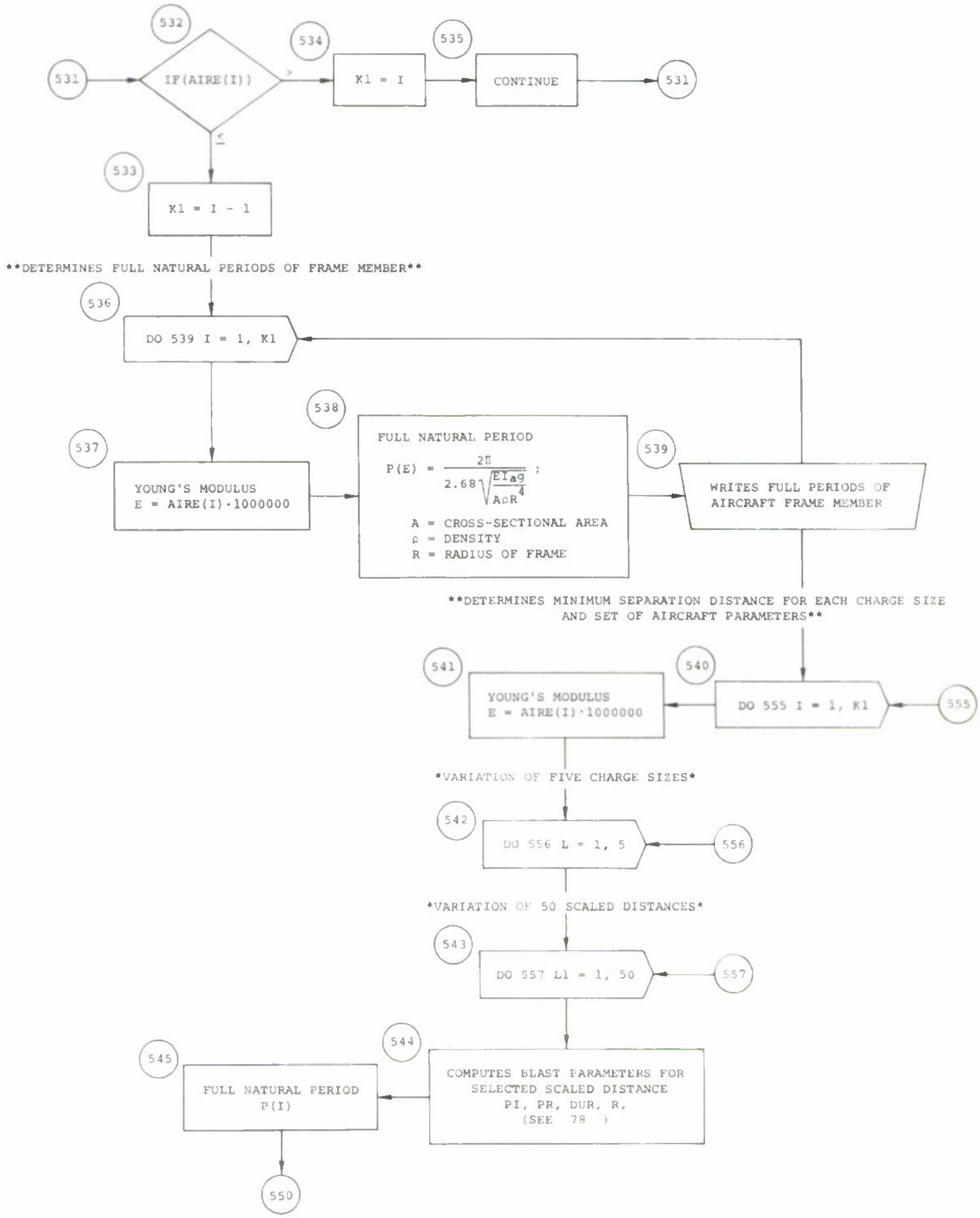

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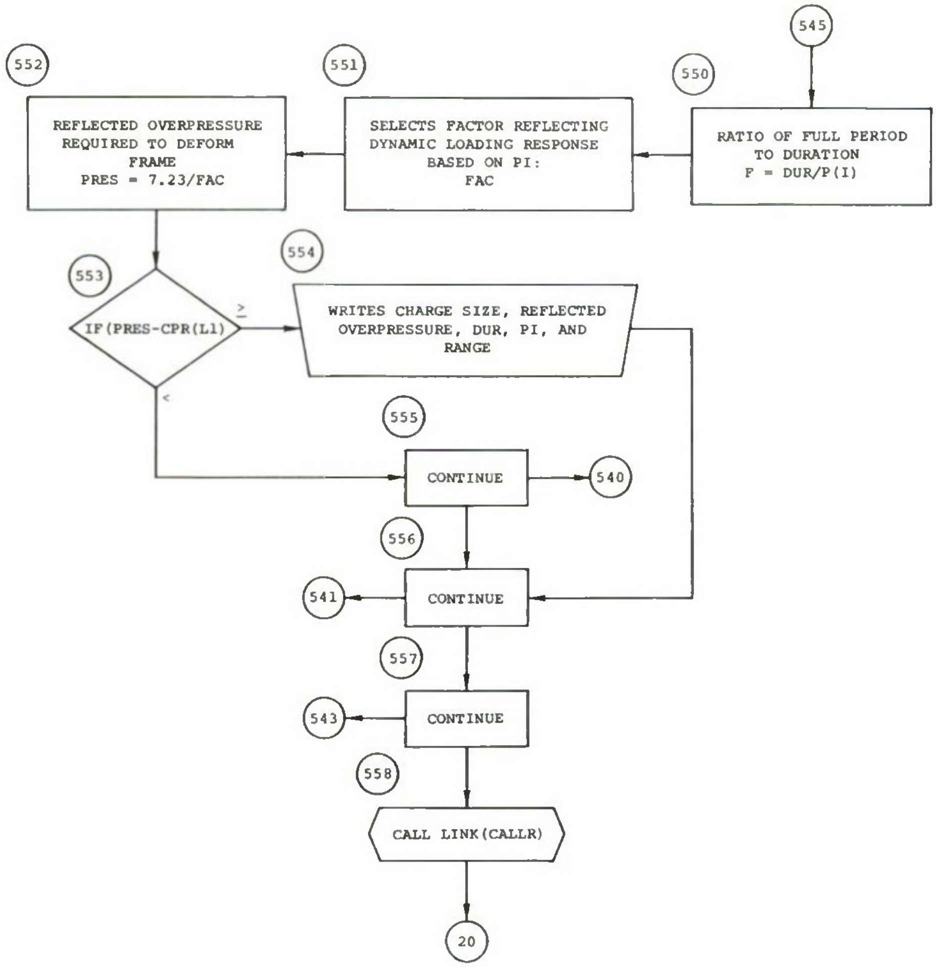

Figure 11 (Continued)

```
// JOB
// DUP
*DELETE             HEADR
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON      PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C     ..............................................................
C     PART 1. INPUT DATA SUBROUTINE
C     ..............................................................
C.....CHARGE SIZES.....
      READ(2,1)(CS(I),I=1,5)
C.....INCIDENT OVERPRESSURES,DURATIONS,AND REFLECTION FACTORS.....
      READ(2,1)(PO(I),I=1,50)
      READ(2,1) (TAU(I),I=1,50)
      READ(2,1) (CPR(I),I=1,50)
C.....HOUSE ROOF PARAMETERS.....
      READ(2,2) (HRE(I),I=1,4)
      READ(2,2) (HRW(I),I=1,4)
      READ(2,2)(HRS(I),I=1,4)
C.....HOUSE FRAME SECTION PARAMETERS.....
      READ(2,2) (HFE(I),I=1,4)
      READ(2,2) (HFW(I),I=1,4)
      READ(2,2) (HFS(I),I=1,4)
C.....HOUSE BRICK WALL SECTION PARAMETERS.....
      READ(2,2) (HBE(I),I=1,4)
      READ(2,2) (HBT(I),I=1,4)
C.....CHURCH ROOF PARAMETERS.....
      READ(2,2) (CRE(I),I=1,4)
      READ(2,2) (CRW(I),I=1,4)
      READ(2,2) (CRS(I),I=1,4)
C.....CHURCH DECKING PARAMETERS.....
      READ(2,2) (CDE(I),I=1,4)
      READ(2,2) (CDW(I),I=1,4)
      READ(2,2) (CDS(I),I=1,4)
C.....SCHOOL BRICK WALL PARAMETERS.....
      READ(2,2) (SBWE(I),I=1,4)
      READ(2,2) (SBT(I),I=1,4)
C.....SCHOOL ROOF PARAMETERS.....
      READ(2,2) (SRE(I),I=1,4)
      READ(2,2) (SRW(I),I=1,4)
      READ(2,2)(SRS(I),I=1,4)
C.....OFFICE BUILDING HALF WALL PARAMETERS.....
      READ(2,2) (OHE(I),I=1,4)
      READ(2,2) (OHT(I),I=1,4)
C.....OFFICE FULL WALL PARAMETERS.....
      READ(2,2) (OFE(I),I=1,4)
      READ(2,2)(OFT(I),I=1,4)
C.....BUS PARAMETERS.....
      READ(2,2) (BCG(I),I=1,4)
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      READ(2,2) (BW(I),I=1,4)
C.....CAMPER AND PICKUP TRUCK PARAMETERS.....
      READ(2,2) (CCG(I),I=1,4)
      READ(2,2) (CTG(I),I=1,4)
      READ(2,2) (TRW(I),I=1,4)
      READ(2,2) (CPW(I),I=1,4)
C.....MOBILE HOME PARAMETERS.....
      READ(2,2) (TRCG(I),I=1,4)
      READ(2,2) (TRWT(I),I=1,4)
C.....IGLOO DOOR PARAMETERS.....
      READ(2,2) (DORS(I),I=1,4)
C.....MAN PARAMETERS.....
      READ(2,2) (WMAN(I),I=1,4)
      READ(2,2) (PMAN(I),I=1,4)
C.....AIRPLANE PARAMETERS.....
      READ(2,2) (AIRE(I),I=1,4)
      READ(2,1) (AIRF(I),I=1,10)
C.....NUMBER OF TARGETS CONSIDERED AND THEIR ORDER.....
      READ(2,3) NOT,IA(1),IA(2),IA(3),IA(4),IA(5),IA(6),IA(7),IA(8),
     *IA(9),IA(10),IA(11)
      K=0
      CALL LINK(CALLR)
    1 FORMAT(5F12.2)
    2 FORMAT(4F12.2)
    3 FORMAT(12I2)
      END
// DUP
*STORE      WS  UA  HEADR
// JOB
// DUP
*DELETE             CALLR
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
C     PART 2. TARGET SUBROUTINE SELECTION
      COMMON        PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
      K=K+1
      IF(K-NOT) 1,1,2
    2 CALL EXIT
C................................................
C.....SELECTION OF TARGET MODEL.....
C................................................
    1 J8=IA(K)
      GO TO (100,200,300,400,500,600,700,800,900,1000,1100),J8
  100 CALL LINK (HOUSE)
  200 CALL LINK(CHRCH)
  300 CALL LINK(SCHOL)
  400 CALL LINK(OHAFW)
  500 CALL LINK(OFULL)
  600 CALL LINK(BUS)
```

```
  700 CALL LINK(CAMPR)
  800 CALL LINK(TRLER)
  900 CALL LINK(DOOR)
 1000 CALL LINK(MAN)
 1100 CALL LINK(AIRP)
      END
// DUP
*STORE      WS  UA  CALLR
// JOB
// DUP
*DELETE             HOUSE
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C...............................................
C     PART 3. HOUSE ROOF SUBROUTINE
C...............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=204.
      AI=51.2
      C=3.75
      G=386.
C.....DETERMINES NO. OF HOUSE ROOF PARAMETERS.....
      DO 100 I=1,4
      IF(HRE(I)) 101,101,100
  101 K1=I-1
      GO TO 146
  100 CONTINUE
      K1=4
C.....DETERMINES NO. OF HOUSE FRAME WALL PARAMETERS.....
  146 DO 127 I=1,4
      IF(HFE(I)) 147,147,127
  147 K2=I-1
      GO TO 128
  127 CONTINUE
      K2=4
C.....DETERMINES NO. OF HOUSE B. WALL PARAMETERS.....
  128 DO 129 J=1,4
      IF(HBE(J)) 130,130,129
  130 K3=J-1
      GO TO 102
  129 CONTINUE
      K3=4
C...............................................
C.....CRITICAL PERIOD AND IMPULSE FOR HOUSE ROOF.....
C...............................................
  102 DO 103 I=1,K1
      E=HRE(I)*1000000.
```

```
      DO 103 II=1,K1
      WI=HRW(II)*8.5
      W=WI/102.
      DO 103 III=1,K1
      SIG=HRS(III)*10000.
      PP=9.87*SQRT((   E*AI*G)/(W*FEET**4.))
      P=PP/5.96
      TC(I,II,III)=1000./(4.*P)
      WO=(SIG*8.*AI)/(C*FEET**2.)
      U=((WO**2.)* (FEET**5.))/(240.*E*AI)
      WT=W*FEET
      H=SQRT(U*2.*WT/G)
  103 UI(I,II,III)=(H*1000.)/3264.
      WRITE(3,3)
      WRITE(3,4)
      WRITE(3,18)
      DO 104 I=1,K1
      DO 104 J=1,K1
      DO 104 J1=1,K1
      E=HRE(I)*1000000.
      SIG=HRS(J1)*10000.
  104 WRITE(3,5) E,HRW(J),SIG,TC(I,J,J1),UI(I,J,J1)
C.....CRITICAL PERIOD AND IMPULSE FOR HOUSE FRAME WALL.....
      DO 131 I=1,K2
      E=HFE(I)*1000000.
      DO 131 J=1,K2
      WI=HFW(J)*7.5
      W=WI/90.
      DO 131 III=1,K2
      SIG=HFS(III)*10000.
      PP=9.87*SQRT((E*6.22*G)/(W*90.**4.))
      P=PP/5.96
      TC2(I,J,III)=1000./(4.*P)
      WO=SIG*8.*6.22/14580.
      U=((WO**2.)*(90.**5.))/(240.*E*6.22)
      WT=W*90.
      H=SQRT(U*2.*WT/G)
  131 UI2(I,J,III)=H*1000./1440.
      WRITE(3,9)
      WRITE(3,4)
      WRITE(3,18)
      DO 132 I=1,K2
      DO 132 J=1,K2
      DO 132 J1=1,K2
      E=HFE(I)*1000000.
      SIG=HFS(J1)*10000.
  132 WRITE(3,5) E,HFW(J),SIG,TC2(I,J,J1),UI2(I,J,J1)
C.....CRITICAL PERIOD FOR HOUSE BRICK WALL.....
      III=1
      DO 133 I=1,K3
      E=HBE(I)*1000000.
      DO 133 J=1,K3
      TS=HBT(J)
      W=.55
      PP=9.87*SQRT((E*42.7*G)/(W*90.**4.))
      P=PP/5.96
  133 TC3(I,J,III)=1000./(4.*P)
```

```
      WRITE(3,10)
      WRITE(3,11)
      WRITE(3,19)
      DO 134 I=1,K3
      DO 134 J=1,K3
      E=HBE(I)*1000000.
  134 WRITE(3,12) E,HBT(J),TC3(I,J,III)
C...............................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C...............................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 105 I=1,K1
      DO 105 J=1,K1
      DO 105 J1=1,K1
      CI=UI(I,J,J1)
      CP=TC(I,J,J1)
      E=HRE(I)*1000000.
      SIG=HRS(J1)*10000.
      WRITE(3,7) E,HRW(J),SIG
C.....VARIATION OF CHARGE SIZE.....
      DO 106 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 107 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 117,117,118
  117 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 119
  118 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  119 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
C.....TIME TO STAG. AND MAX. AVER. PRESSURE ON ROOF
      TA=(15.7/(2.*VEL))*1000.
      TS=2.*TA
      PTS=PR*(1.-TA/DUR)*EXP(-TA/DUR)-.3*QO*(1.-TA/DUR)**2.*EXP(-2.*TA
     */DUR)
      IF(CP-DUR) 120,120,121
C.....CASE I. CRITICAL PERIOD LESS THAN DURATION.....
  120 TIME=TS+.5*(CP-TS)
      TIMS=TIME-TA
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*PTS*TS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME-TS)+.5*PTI
     **(CP-TIME)
      GO TO 122
C.....CASE II. CRITICAL PERIOD GREATER THAN DURATION.....
  121 TIME=TS+.5*(DUR-TS)
      TIMS=TIME-TA
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*PTS*TS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME-TS)+.5*PTI
     **(DUR-TIME)
```

```
  122 IF(CI-CALI) 107,126,126
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  126 PRO=PTS
      WRITE(3,8) CS(L),R
      WRITE(3,17) PI,PR,DUR
C.....CRITICAL IMP AND CALCULATED IMP. FOR HOUSE FRAME ARE
C.....COMPARED FOR THIS SELECTED CHARGE AND DISTANCE.....
      WRITE(3,13)
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 170,171,171
  171 WRITE(3,50) PI
      GO TO 172
  170 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 173,174,174
  174 WRITE(3,51) PI
      GO TO 172
  173 M=((FV-CV)/50.)
      S=M*.1+.1
      WRITE(3,52) PI,S
  172 DO 135 I1=1,K2
      DO 135 I2=1,K2
      DO 135 I3=1,K2
C.....BLAST LOADING ON OUTSIDE OF FRAME SECTION.....
      TS=(10.8/VEL)*1000.
      DP=TC2(I1,I2,I3)
      PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
      IF(DP-TS) 136,136,137
C.....CASE I. CRITICAL PERIOD LESS THAN TIME TO STAG......
  136 CALF=.5*(PR-PTS)*TS+TS*PTS
      GO TO 140
  137 IF(DP-DUR) 138,138,139
C.....CASE II. C PERIOD LESS THAN DURATION.....
  138 PCP=PI*(1.-DP/DUR)*EXP(-DP/DUR)+QO*(1.-DP/DUR)**2.*EXP(-2.
     **DP/DUR)
      CALF=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-PCP)*(DP-TS)+PCP*(DP-TS)
      GO TO 140
  139 CALF=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(DUR-TS)
C.....BLAST LOADING ON BACK OF FRAME WALL.....
  140 PTF=PI*(1.-17./DUR)*EXP(-17./DUR)
      IF(DP-DUR) 148,148,149
  148 PCP=PI*(1.-DP/DUR)*EXP(-DP/DUR)
      CALB=.5*PTF*17.+.5*(PTF-PCP)*(DP-17.)+(DP-17.)*PCP
      GO TO 150
  149 CALB=.5*PTF*17.+.5*PTF*(DP-17.)
  150 CALI=CALF-CALB
  135 WRITE(3,14) UI2(I1,I2,I3),CALI
C.....CRITICAL IMPULSE AND CALCULATED IMP. FOR HOUSE BRICK WALL
C.....ARE COMPARED FOR SELECTED CHARGE AND DISTANCE.....
      WRITE(3,15)
      I6=1
      DO 145 I4=1.K3
      DO 145 I5=1,K3
C.....CRITICAL IMPULSE OF BRICK WALL IS FUNCTION OF BLAST
```

```
C.....LOADING ON ROOF
      E=HBE(I4)*1000000.
      TW=8.
      TST=HBT(I5)
      TS=(3.*3./VEL)*1000.
      DP=TC3(I4,I5,I6)
      PV=15.9+.5*PRO*230.4
      Q1=32.*(TST*8.+PV)/270.
      Y1=(5.*90**3.*Q1)/(384.*E*42.7)
      Q2=(4.*(8.-Y1)*(2.*PV+50.))/90.
      CQ2=(4.*(TW-7.)*(2.*PV+50.))/90.
      WORK=(5.*Y1*Q1)+(.5*(7.-Y1)*(Q2-CQ2))+CQ2*(7.-Y1)
      VSQ=WORK/.0431
      V=SQRT(VSQ)
      ZI=(25./G)*V+.012*V
      UI3(I4,I5,I6)=(ZI*1000./45.)*.5
      IF(DUR-TS) 141,141,142
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  141 CALI=.5*PR*DUR
      GO TO 145
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  142 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
C.....CALCULATES POINT OF MINIMUM EFFECTIVE PRESSURE.....
      DIV=(DUR-TS)/50.
      DO 143 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 144,144,143
  143 CONTINUE
  144 CALI=.5*TS*(PR-PTS)+TS*PTS+.5*PTS*(TEND-TS)
  145 WRITE(3,14) UI3(I4,I5,I6),CALI
      GO TO 106
  107 CONTINUE
  106 CONTINUE
  105 CONTINUE
      CALL LINK(CALLR)
    3 FORMAT(1X,'CRITICAL PERIOD AND IMPULSE FOR HOUSE ROOF',//)
    4 FORMAT(1X,'E',8X,'WEIGHT',8X,'M.OF RUPT',8X,'C PERIOD',8X,
     *'C IMPULSE',)
    5 FORMAT(F9.0,4F12.2)
    7 FORMAT(1X,'MINIMUM DIST. FOR E=',F8.0,1X,'WEIGHT=',F10.2,1X,
     *1X,'M.OF RUPT=',F10.2,/)
    8 FORMAT(1X,'CHARGE WEIGHT=',F8.0,10X,'DISTANCE=',F10.2,/)
    9 FORMAT(1X,'CRITICAL PERIOD AND IMPULSE FOR H FRAME SECTION',//)
   10 FORMAT(1X,'CRITICAL PERIOD FOR HOUSE BRICK WALL',//)
   11 FORMAT(1X,'E',10X,'TENSILE STRENGTH',10X,'C PERIOD', )
   12 FORMAT(F9.0,2F10.2)
   13 FORMAT(20X,'HOUSE FRAME SECTION',/)
   14 FORMAT(15X,'REQUIRED IMPULSE=',F10.2,2X,'CALC. IMPULSE=',F10.2,)
   15 FORMAT(20X,'HOUSE BRICK WALL',/)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   18 FORMAT(1X,'LBS/SQ IN',6X,'LBS/FT',6X,'LBS/SQ IN',6X,'MSEC',
     *6X,'PSI-MS',/)
```

```
   19 FORMAT(1X,'LBS/SQ IN',10X,'LBS/SQ IN',10X,'MSEC',/)
   50 FORMAT(1X,'FRAGMENT  SIZES AT PI=',F10.2,'ARE TOO SMALL TO CAUSE',
     *1X,'SERIOUS INJURY',/)
   51 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB. OF SERIOUS WOUNDS=0.',/)
   52 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB.OF SERIOUS WOUNDS=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURYZ',)
      END
// DUP
*STORE      WS  UA  HOUSE
// JOB
// DUP
*DELETE             CHRCH
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C.............................................
C     PART IV. CHRCH SUBROUTINE
C.............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=468.
      AI=2545.
      C=7.95
      G=386.
C.....DETERMINES NO. OF CHURCH ROOF PARAMETERS
      DO 200 I=1,4
      IF(CRE(I)) 201,201,200
  201 K1=I-1
      GO TO 223
  200 CONTINUE
      K1=4
C.....DETERMINES NO. OF CHURCH ROOF DECKING PARAMETERS.....
  223 DO 218 I=1,4
      IF(CDE(I)) 219,219,218
  219 K2=I-1
      GO TO 202
  218 CONTINUE
      K2=4
C.............................................
C.....CRITICAL PERIOD AND IMPULSE FOR CHURCH ROOF.....
C.............................................
  202 DO 203 I=1,K1
      E=CRE(I)*1000000.
      DO 203 II=1,K1
      WI=CRW(II)*32.
      W=WI/468.
      DO 203 III=1,K1
      SIG=CRS(III)*10000.
      PP=9.87*SQRT((  E*AI*G)/(W*FEET**4.))
```

```
      P=PP/5.96
      TC(I,II,III)=1000./(4.*P)
      WO=(SIG*8.*AI)/(C*FEET**2.)
      U=((WO**2.)* (FEET**5.))/(240.*E*AI)
      WT=W*FEET+140.
      H=SQRT(U*2.*WT/G)
  203 UI(I,II,III)=(H*1000.)/84240.
      WRITE(3,6)
      WRITE(3,4)
      WRITE(3,18)
      DO 204 I=1,K1
      DO 204 J=1,K1
      DO 204 J1=1,K1
      E=CRE(I)*1000000.
      SIG=CRS(J1)*10000.
  204 WRITE(3,5) E,CRW(J),SIG,TC(I,J,J1),UI(I,J,J1)
C.....CRITICAL PERIOD AND IMPULSE FOR CHURCH DECKING.....
      DO 220 I=1,K2
      E=CDE(I)*1000000.
      DO 220 J=1,K2
      WI=CDW(J)*15.
      W=WI/180.
      DO 220 III=1,K2
      SIG=CDS(III)*10000.
      PP=9.87*SQRT((E*46.65*G)/(W*180.**4.))
      P=PP/5.96
      TC2(I,J,III)=1000./(4.*P)
      WO=SIG*8.*46.65/(1.8*180.**2.)
      U=((WO**2.)*(180.**5.))/(240.*E*46.65)
      WT=W*180.
      H=SQRT(U*2.*WT/G)
  220 UI2(I,J,III)=H*1000./2160.
      WRITE(3,9)
      WRITE(3,4)
      WRITE(3,18)
      DO 221 I=1,K2
      DO 221 J=1,K2
      DO 221 J1=1,K2
      E=CDE(I)*1000000.
      SIG=CDS(J1)*10000.
  221 WRITE(3,5) E,CDW(J),SIG,TC2(I,J,J1),UI2(I,J,J1)
C................................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C................................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 205 I=1,K1
      DO 205 J=1,K1
      DO 205 J1=1,K1
      CI=UI(I,J,J1)
      CP=TC(I,J,J1)
      E=CRE(I)*1000000.
      SIG=CRS(J1)*10000.
      WRITE(3,7) E,CRW(J),SIG
C.....VARIATION OF CHARGE SIZE.....
      DO 206 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
```

```
      DO 207 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 208,208,209
  208 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 210
  209 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  210 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      TA=(15.25/(2.*VEL))*1000.
      TS=2.*TA
      PTS=PR*(1.-TA/DUR)*EXP(-TA/DUR)-.3*QO*(1.-TA/DUR)**2.*EXP(-2.
     **TA/DUR)
      IF(CP-DUR) 211,211,212
C.....CASE I. CRITICAL PERIOD LESS THAN DURATION.....
  211 TIME=TS+.5*(CP-TS)
      TIMS=TIME-TA
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*PTS*TS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME-TS)+.5*PTI
     **(CP-TIME)
      GO TO 213
C.....CASE II. CRITICAL PERIOD GREATER THAN DURATION.....
  212 TIME=TS+.5*(DUR-TS)
      TIMS=TIME-TA
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*PTS*TS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME-TS)+.5*PTI
     **(DUR-TIME)
  213 IF(CI-CALI) 207,217,217
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  217 WRITE(3,8) CS(L),R
      WRITE(3,17) PI,PR,DUR
C..................................................
C.....CRITICAL IMP AND CALCULATED IMP. FOR CHURCH DECKING
C.....ARE COMPARED FOR THIS SELECTED CHARGE AND DISTANCE.....
C..................................................
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 270,271,271
  271 WRITE(3,50) PI
      GO TO 272
  270 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 273,274,274
  274 WRITE(3,51) PI
      GO TO 272
  273 M=((FV-CV)/50.)
      S=M*.1+.1
      WRITE(3,52) PI,S
  272 WRITE(3,10)
      DO 222 I1=1,K2
```

```
      DO 222 I2=1,K2
      DO 222 I3=1,K2
      DP=TC2(I1,I2,I3)
      TS=(1.5/VEL)*1000.
      PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)-.3*QO*(1.-TS/DUR)**2.
     **EXP(-2.*TS/DUR)
      IF(DP-DUR) 224,224,225
C.....CASE I. CRITICAL PERIOD LESS THAN DURATION.....
  224 TIME=TS+.5*(DP-TS)
      TIMS=TIME
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME
     * -TS)+.5*PTI*(DP-TIME)
      GO TO 222
C.....CASE II. CRITICAL PERIOD GREATER THAN DURATION.....
  225 TIME=TS+.5*(DUR-TS)
      TIMS=TIME
      PTI=PI*(1.-TIMS/DUR)*EXP(-TIMS/DUR)-.3*QO*(1.-TIMS/DUR)**2.
     **EXP(-2.*TIMS/DUR)
      CALI=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-PTI)*(TIME-TS)+PTI*(TIME
     *-TS)+.5*PTI*(DUR-TIME)
  222 WRITE(3,11) UI2(I1,I2,I3),CALI
      GO TO 206
  207 CONTINUE
  206 CONTINUE
  205 CONTINUE
      CALL LINK(CALLR)
    4 FORMAT(1X,'F',8X,'WEIGHT',8X,'M.OF RUPT',8X,'C PERIOD',8X,
     *'C IMPULSE',)
    5 FORMAT(F9.0,4F12.2)
    6 FORMAT(1X,'CRITICAL PERIOD AND IMPULSE FOR CHURCH ROOF',//)
    7 FORMAT(1X,'MINIMUM DIST. FOR F=',F8.0,1X,'WEIGHT=',F10.2,1X,
     *1X,'M.OF RUPT=',F10.2,/)
    8 FORMAT(1X,'CHARGE WEIGHT=',F8.0,10X,'DISTANCE=',F10.2,/)
    9 FORMAT(1X,'CRITICAL PERIOD AND IMPULSE FOR C DECKING',//)
   10 FORMAT(20X,'CHURCH DECKING',/)
   11 FORMAT(15X,'REQUIRED IMPULSE=',F10.2,2X,'CALC IMPULSE=',F10.2,)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   18 FORMAT(1X,'LBS/SQ IN',6X,'LBS/FT',6X,'LBS/SQ IN',6X,'MSEC',
     *6X,'PSI-MS',/)
   50 FORMAT(1X,'FRAGMENT SIZES AT PI=',F10.2,'ARE TOO SMALL TO CAUSE',
     *1X,'SERIOUS INJURY',/)
   51 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB. OF SERIOUS WOUNDS=0.',/)
   52 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB OF SERIOUS WOUNDS=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURYZ',)
      END
// DUP
*STORE      WS  UA  CHRCH
// JOB
// DUP
*DELETE             SCHOL
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
```

```
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRE(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C.............................................
C     PART V. SCHOL SUBROUTINE
C.............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=126.
      TW=8.
      AI=42.7
      G=386.
      III=1
C.....DETERMINES NO. OF SCHOOL B. WALL PARAMETERS.....
      DO 300 I=1,4
      IF(SBWE(I)) 301,301,300
  301 K1=I-1
      GO TO 329
  300 CONTINUE
      K1=4
C.....DETERMINES NO. OF SCHOOL ROOF PARAMETERS.....
  329 DO 330 I=1,4
      IF(SRE(I)) 331,331,330
  331 K2=I-1
      GO TO 302
  330 CONTINUE
      K2=4
C.....CRITICAL PERIOD FOR SCHOOL BRICK WALL.....
  302 DO 303 I=1,K1
      F=SBWE(I)*1000000.
      DO 303 II=1,K1
      TS=SBT(II)
      W=.55
      PP=9.87*SQRT((  F*AI*G)/(W*FEET**4.))
      P=PP/5.96
  303 TC(I,II,III)=1000./(4.*P)
      WRITE(3,9)
      WRITE(3,14)
      WRITE(3,54)
      DO 304 I=1,K1
      DO 304 J=1,K1
      III=1
      F=SBWE(I)*1000000.
  304 WRITE(3,11) F,SBT(J),TC(I,J,III)
C.............................................
C.....CRITICAL PERIOD AND IMPULSE FOR SCHOOL ROOF.....
C.............................................
      DO 332 I=1,K2
      E=SRE(I)*1000000.
      DO 332 J=1,K2
      WI=SRW(J)*28.
      W=WI/336.
      DO 332 III=1,K2
```

```
      SIG=SRS(III)*10000.
      PP=9.87*SQRT((E*517.41*G)/(W*336**4.))
      P=PP/5.96
      TC2(I,J,III)=1000./(4.*P)
      WO=(SIG*8.*517.41)/(6.6*336.**2.)
      U=((WO**2.)*(336.**5.))/(240.*E*517.14)
      WT=W*336.
      H=SQRT(U*2.*WT/G)
  332 UI2(I,J,III)=H*1000./8064.
      WRITE(3,13)
      WRITE(3,16)
      WRITE(3,55)
      DO 333 I=1,K2
      DO 333 J=1,K2
      DO 333 III=1,K2
      E=SRE(I)*1000000.
      SIG=SRS(III)*10000.
  333 WRITE(3,17) E,SRW(J),SIG,TC2(I,J,III),UI2(I,J,III)
C..............................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C..............................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 305 I=1,K1
      DO 305 J=1,K1
      CP=TC(I,J,III)
      E=SBWE(I)*1000000.
      WRITE(3,12) E,SBT(J)
C.....VARIATION OF CHARGE SIZE.....
      DO 306 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 307 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 308,308,309
  308 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 310
  309 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  310 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      TA=(28./(2.*VEL))*1000.
      PTA=PI*(1.-TA/DUR)*EXP(-TA/DUR)-.4*QO*(1.-TA/DUR)**2.*EXP(-2.
     **TA/DUR)
C.....CRITICAL IMPULSE OF SCHOOL B WALL IS FUNCTION OF LOADING ON ROOF
      PV=75.-L1*1.
      TST=SBT(J)
      Q1=(4.*TW)*(TST*TW+PV)/(3.*FEET)
      Y1=(5.*FEET**3.*Q1)/(384.*E*AI)
      Q2=(4.*(TW-Y1)*(2.*PV+70.))/FEET
      CQ2=(4.*(TW-7.)*(2.*PV+70.))/FEET
      WORK=(.5*Y1*Q1)+(.5*(7.-Y1)*(Q2-CQ2))+CQ2*(7.-Y1)
      VSQ=WORK/.064
      V=SQRT(VSQ)
      TI=(35./G )*V+.038*V
```

```
      CI=TI*1000./63.
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      TS=(3.*10.5/VEL)*1000.
      IF(DUR-TS) 325,326,326
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  325 CALI=.5*PR*DUR
      GO TO 314
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  326 DIV=(DUR-TS)/50.
C.....CALCULATES POINT OF MINIMUM EFFECTIVE PRESSURE.....
      DO 327 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.3 ) 328,328,327
  327 CONTINUE
  328 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
      IF(TS-CP) 311,311,312
C.....C. PERIOD LESS THAN TIME TO STAG.....
  312 AVER=(PTS+PR)/2.
      IF(AVER-.5) 319,313,313
  313 CALI=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
      GO TO 314
C.....C. PERIOD GREATER THAN TIME TO STAG.....
  311 IF(CP-TEND) 320,320,321
  320 PCP=PI*(1.-CP/DUR)*EXP(-CP/DUR)+QO*(1.-CP/DUR)**2.*EXP(-2.
     **CP/DUR)
      AVER=(PR+PCP)/2.
      IF(AVER-.5) 319,316,316
  316 CALI=.5*(PR-PTS)*TS+TS*PTS+PCP*(CP-TS)+.5*(PTS-PCP)*(CP-TS)
     *+.5*PCP*(TEND-CP)
      GO TO 314
  321 AVER=PR/2.
      IF(AVER-.5) 319,323,323
  323 CALI=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
  314 IF(CI-CALI) 307,319,319
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  319 WRITE(3,15) CS(L),R,CI
      WRITE(3,47) PI,PR,DUR
C.................................................
C.....CRITICAL IMPULSE AND CALCULATED IMPULSE FOR SCHOOL ROOF
C.....ARE COMPARED FOR THIS SELECTED CHARGE AND DISTANCE.....
C.................................................
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 370,371,371
  371 WRITE(3,50) PI
      GO TO 372
  370 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 373,374,374
  374 WRITE(3,51) PI
      GO TO 372
  373 M=((FV-CV)/50.)
```

```
      S=M*.1+.1
      WRITE(3,52) PI,S
  372 WRITE(3,19)
      DO 334 I1=1,K2
      DO 334 I2=1,K2
      DO 334 I3=1,K2
      DP=TC2(I1,I2,I3)
      TA=(28./VEL)*1000.
C.....TIME AND MAX. AVER. PRESSURE ON SCHOOL ROOF.....
      TZ=( 28./(2.*VEL))*1000.
      PTZ=PI*(1.-TZ/DUR)*EXP(-TZ/DUR)-.3*QO*(1.-TZ/DUR)**2.*EXP(-2.
     **TZ/DUR)
      IF(DUR-TA) 335,335,336
  335 CALI=.5*(PTZ*DUR/TA)*DUR
      GO TO 334
  336 IF(DP-TA) 337,337,338
  337 CALI=.5*(PTZ*DP/TA)*DP
      GO TO 334
  338 IF(DP-DUR) 339,339,340
  339 TIME=DP-TZ
      PTI=PI*(1.-TIME/DUR)*EXP(-TIME/DUR)-.3*QO*(1.-TIME/DUR)**2.
     **EXP(-2.*TIME/DUR)
      CALI=.5*PTZ*TA+.5*(PTZ-PTI)*(DP-TA)+PTI*(DP-TA)
      GO TO 334
  340 CALI=.5*PTZ*TA+.5*PTZ*(DUR-TA)
  334 WRITE(3,18) UI2(I1,I2,I3),CALI
      GO TO 306
  307 CONTINUE
  306 CONTINUE
  305 CONTINUE
      CALL LINK(CALLR)
    9 FORMAT(1X,'CRITICAL PERIOD FOR SCHOOL BRICK WALL',/)
   11 FORMAT(3F15.2)
   12 FORMAT(1X,'MINIMUM DISTANCE FOR E=',F10.2,'T STRENGTH=',F10.2,/)
   13 FORMAT(1X,'CRITICAL PERIOD AND IMPULSE FOR SCHOOL ROOF',/)
   14 FORMAT(1X,'E',10X,'TENSILE STRENGTH',10X,'C PERIOD',)
   15 FORMAT(1X,'CHARGE WEIGHT=',F10.2,'DISTANCE=',F10.2,'UNIT IMPULSE=',
     *F10.2,/)
   16 FORMAT(1X,'E',8X,'WEIGHT',8X,'M.OF RUPT',8X,'C PERIOD',8X,
     *'C IMPULSE',)
   17 FORMAT(F9.0,4F12.2)
   19 FORMAT(10X,'SCHOOL ROOF SECTION',/)
   18 FORMAT(15X,'REQUIRED IMPULSE=',F10.2,2X,'CALC. IMPULSE=',F10.2,)
   47 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   50 FORMAT(1X,'FRAGMENT SIZES AT PI=',F10.2,'ARE TOO SMALL TO CAUSE',
     *1X,'SERIOUS INJURY',/)
   51 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB.OF SERIOUS WOUNDS=0.',/)
   52 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB. OF SERIOUS WOUNDS=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURYZ',)
   54 FORMAT(1X,'LBS/SQ IN',10X,'LBS/SQ IN',10X,'MSEC',/)
   55 FORMAT(1X,'LBS/SQ IN',6X,'LBS/FT',6X,'LBS/SQ IN',6X,'MSEC',
     *6X,'PSI-MS',/)
      END
// DUP
*STORE      WS  UA  SCHOL
// JOB
```

```
// DUP
*DELETE             OHAFW
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C.............................................
C     PART VI. OFFCE SUBROUTINE
C.............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=96.
      DI=216.
      TW=8.
      G=386.
      AIP=42.7
      III=1
C.....DETERMINES NO. OF PARAMETERS FOR OFFICE HALF WALL.....
      DO 400 I=1,4
      IF(OHE(I)) 401,401,400
  401 K1=I-1
      GO TO 402
  400 CONTINUE
      K1=4
C.............................................
C.....CRITICAL PERIOD FOR OFFICE HALF WALL.....
C.............................................
  402 DO 403 I=1,K1
      E=OHE(I)*1000000.
      DO 403 II=1,K1
      TE=OHT(II)
      SIG=1300000.
      W=.2
      PP=9.87*SQRT(( E*AIP*G)/(W*DI**4.))
      P=PP/5.96
  403 TC(I,II,III)=(1000./(4.*P))*.67
      WRITE(3,13)
      WRITE(3,14)
      WRITE(3,19)
      DO 404 I=1,K1
      DO 404 J=1,K1
      III=1
      E=OHE(I)*1000000.
  404 WRITE(3,11) E,OHT(J),TC(I,J,III)
C.............................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C.............................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 405 I=1,K1
```

```
      DO 405 J=1,K1
      CP=TC(I,J,III)
      E=OHE(I)*1000000.
      WRITE(3,12) E,OHT(J)
C.....VARIATION OF CHARGE SIZE.....
      DO 406 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 407 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 408,408,409
  408 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 410
  409 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  410 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
C.....CRITICAL IMP. ON BRICK WALL IS FUNCTION OF BLAST LOADING
C.....ON TOP OF WALL.....
      PV=26.-L1*.15
      TST=OHT(J)
      Q1=(4.*TW)*(TST*TW+PV)/(3.*FEET)
      Y1=(5.*FEET**3.*Q1)/(384.*E*AIP)
      Q2=(4.*(TW-Y1)*(2.*PV+9.3))/FEET
      CQ2=(4.*(TW-5.)*(2.*PV+9.3))/FEET
      WORK=(.5*Y1*Q1)+(.5*(7.-Y1)*(Q2-CQ2))+CQ2*(7.-Y1)
      VSQ=WORK/.058
      V=SQRT(VSQ)
      TI=(26.6/G)*V+.024*V
      CI=TI*1000./48.
      TS=(3.*4./VEL)*1000.
      PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+   QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
C.....CALCULATES POINT OF MINIMUM EFFECTIVE PRESSURE.....
      DIV=(DUR-TS)/50.
      DO 431 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 433,433,431
  431 CONTINUE
  433 IF(TS-CP) 411,411,412
C.....C. PERIOD LESS THAN TIME TO STAG.....
  412 AVER=(PTS+PR)/2.
      IF(AVER-.5) 428,413,413
  413 CALF=.5*TS*(PR-PTS)+TS*PTS+.5*PTS*(TEND-TS)
      GO TO 419
C.....C. PERIOD GREATER THAN TIME TO STAG.....
  411 IF(CP-TEND) 416,416,415
  416 PCP=PI*(1.-CP/DUR)*EXP(-CP/DUR)+   QO*(1.-CP/DUR)**2.*EXP(-2.
     **CP/DUR)
      AVER=(PR+PCP)/2.
      IF(AVER-.5) 428,430,430
```

```
  430 CALF=TS*PTS+.5*(PR-PTS)*TS+.5*(PTS-PCP)*(CP-TS)+PCP*(CP-TS)
     *+.5*PCP*(TEND-CP)
      GO TO 419
  415 AVER=PR/2.
      IF(AVER-.5) 428,418,418
  418 CALF=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
C.....BLAST LOADING ON REAR OF HALF WALL.....
  419 TA=(16.67/VEL)*1000.
      PTA=PI*(1.-16./DUR)*EXP(-16./DUR)-.3*QO*(1-16./DUR)**2.
     **EXP(-32./DUR)
      IF(TEND-TA) 480,480,481
  480 CALB=.5*(PTA*TEND/TA)*TEND
      GO TO 482
  481 T5=TA+.5*(TEND-TA)
      PT5=PI*(1.-T5/DUR)*EXP(-T5/DUR)-.3*QO*(1.-T5/DUR)**2.
     **EXP(-2.*T5/DUR)
      CALB=.5*PTA*TA+.5*(PTA-PT5)*(T5-TA)+PT5*(T5-TA)+.5*PT5*(TEND-T5)
  482 CALI=CALF-CALB
      IF(CI-CALI) 407,428,428
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  428 WRITE(3,15) CS(L),R,CI
      WRITE(3,17) PI,PR,DUR
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 470,471,471
  471 WRITE(3,50) PI
      GO TO 472
  470 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 473,474,474
  474 WRITE(3,51) PI
      GO TO 472
  473 M=((FV-CV)/50.)
      S=M*.1+.1
      WRITE(3,52) PI,S
  472 GO TO 406
  407 CONTINUE
  406 CONTINUE
  405 CONTINUE
      CALL LINK(CALLR)
   11 FORMAT(3F15.2)
   12 FORMAT(1X,'MINIMUM DISTANCE FOR E=',F10.2,'T STRENGTH=',F10.2,/)
   13 FORMAT(1X,'CRITICAL PERIOD FOR OFFICE HALF WALL',/)
   14 FORMAT(1X,'E',10X,'TENSILE STRENGTH',10X,'C PERIOD',//)
   15 FORMAT(1X,'CHARGE WEIGHT=',F9.0 ,'DISTANCE=',F10.2,'UNIT IMPULSE=',
     *F10.2,/)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   19 FORMAT(1X,'LBS/SQ IN',10X,'LBS/SQ IN',10X,'MSEC',/)
   50 FORMAT(1X,'FRAGMENT SIZES AT PI=',F10.2,'ARE TOO SMALL TO CAUSE',
     *1X,'SERIOUS INJURY',/)
   51 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB. OF SERIOUS WOUNDS=0.',/)
   52 FORMAT(1X,'FOR PI=',F10.2,2X,'PROB.OF SERIOUS WOUNDS=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURY', )
      END
// DUP
```

```
*STORE       WS  UA   OHAFW
// JOB
// DUP
*DELETE                OFULL
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*+OCS(CARD,1132 PRINTER)
      COMMON  PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HEE(4),
     *HEW(4),HES(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFF(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C.................................................
C     PART 7 OFFICE FULL WALL SUBROUTINE
C.................................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=96.
      AI=42.5
      G=386.
      III=1
      DO 500 I=1,4
C.....DETERMINES NO. OF OFFICE FULL WALL PARAMETERS.....
      IF(OFF(I)) 501,501,500
  501 K1=I-1
      GO TO 502
  500 CONTINUE
      K1=4
C.................................................
C.....CRITICAL PERIOD FOR OFFICE FULL WALL.....
C.................................................
  502 DO 503 I=1,K1
      E=OFF(I)*1000000.
      DO 503 II=1,K1
      TS=OFT(II)
      W=.21
      PP=9.87*SQRT((E*AI*G)/(W*FEET**4.))
      P=PP/5.96
  503 TC(I,II,III)=1000./(4.*P)
      WRITE(3,17)
      WRITE(3,14)
      WRITE(3,19)
      DO 504 I=1,K1
      DO 504 J=1,K1
      III=1
      E=OFF(I)*1000000.
  504 WRITE(3,11) E,OFT(J),TC(I,J ,III)
C.................................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C.................................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 505  I=1,K1
      DO 505  J=1,K1
```

```
      CP=TC(I,J,III)
      E=OFF(I)*1000000.
      WRITE(3,12) E,OFT(J)
C.....VARIATION OF CHARGE SIZE.....
      DO 506 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 507 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 508,508,509
  508 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 510
  509 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  510 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      WORK=708.
      VSQ=WORK/.0163
      V=SQRT(VSQ)
      TI=(9.4/G)*V+.008*V
      CI=TI*1000./48.
      TS=(3.*8./VEL)*1000.
      IF(DUR-TS) 511,512,512
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  511 CALI=.5*PR*DUR
      GO TO 514
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  512 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
      DIV=(DUR-TS)/50.
      DO 513 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 519,519,513
  513 CONTINUE
  519 IF(TS-CP) 515,515,516
C.....CASE I. CRITICAL PERIOD LESS THAN TIME TO STAG......
  516 AVER=(PTS+PR)/2.
      IF(AVER-5.) 517,518,518
  518 CALI=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
      GO TO 514
C.....CASE II. C. PERIOD GREATER THAN TIME TO STAG......
  515 IF(CP-TEND) 520,520,521
  520 PCP=PI*(1.-CP/DUR)*EXP(-CP/DUR)+QO*(1.-CP/DUR)**2.*EXP(-2.
     **CP/DUR)
      AVER=(PR+PCP)/2.
      IF(AVER-5.) 517, 522,522
  522 CALI=.5*(PR-PTS)*TS+TS*PTS+PCP*(CP-TS)+.5*(PTS-PCP)*(CP-TS)
     *+.5*PCP*(TEND-CP)
      GO TO 514
  521 AVER=PR/2.
      IF(AVER-5.) 517,523,523
```

```
  523 CALI=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  514 IF(CI-CALI) 507,517,517
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  517 WRITE(3,15) CS(L),R,CI
      WRITE(3,37) PI,PR,DUR
      GO TO 506
  507 CONTINUE
  506 CONTINUE
  505 CONTINUE
      CALL LINK(CALLR)
   11 FORMAT(F10.0,2F15.2)
   12 FORMAT(1X,'MINIMUM DISTANCE FOR E='F9.0,5X,'T STRENGTH=',F10.2,/)
   14 FORMAT(1X,'E',10X,'TENSILE STRENGTH',10X,'C PERIOD',//)
   15 FORMAT(1X,'CHARGE WEIGHT=',F9.0 ,'DISTANCE=',F10.2,
     *'UNIT IMPULSE=',F10.2,/)
   17 FORMAT(1X,'CRITICAL PERIODS FOR OFFICE FULL WALL',/)
   19 FORMAT(1X,'LBS/SQ IN',10X,'LBS/SQ IN',10X,'MSEC',)
   37 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,//)
      END
// DUP
*STORE      WS  UA  OFULL
// JOB
// DUP
*DELETE             BUS
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRF(4),HRW(4),HRS(4),HFF(4),
     *HFW(4),HFS(4),HBF(4),HBT(4),CRF(4),CRW(4),CRS(4),CDF(4),CDW(4),
     *CDS(4),SBWF(4),SBT(4),SRF(4),SRW(4),SRS(4),OHF(4),OHT(4),OFF(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRF(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C............................................
C     BUS OVERTURN SUBROUTINE
C............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      BASE=42.
      III=1
C.....DETERMINES NO. OF BUS PARAMETERS.....
      DO 600 I=1,4
      IF(BCG(I))601,601,600
  601 K1=I-1
      GO TO 602
  600 CONTINUE
      K1=4
C............................................
C.....CRITICAL IMPULSE FOR BUS
C............................................
  602 DO 603 I=1,K1
      CG=BCG(I)
      DO 603 II=1,K1
```

```
      W=BW(II)
      DIST=SQRT(BASE**2.+CG**2.)
      R=DIST*.939
      S=DIST*.342
      RISE=R-CG
      SLID=BASE-S
      WORK=BW(II)*RISE-SLID*.364*BW(II)
      AI=(BW(II)/386.)*((86.5**2.+90.**2.)/12. +60.**2.)
      AIA=.5*AI
      OMGA=WORK/AIA
      OMGA=SQRT(OMGA)
      PULSE=(AI*OMGA)/72.
  603 UI(I,II,III)=PULSE*1000./50400.
      WRITE(3,18)
      WRITE(3,19)
      WRITE(3,25)
      DO 604 I=1,K1
      DO 604 J=1,K1
      W=BW(I)
      CG=BCG(J)
      CI=UI(I,J,III)
  604 WRITE(3,20) W,CG,CI
C..............................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C..............................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 605 I=1,K1
      W=BW(I)
      DO 605 J=1,K1
      CG=BCG(J)
      WRITE(3,24) W,CG
C.....VARIATION OF CHARGE SIZE.....
      DO 606 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 607 L1=1,50
      CI=UI(I,J,III)
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 608,608,609
  608 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 610
  609 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  610 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      TS=(3.*10.5/VEL)*1000.
      IF(DUR-TS)611,612,612
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  611 CALI=.5*PR*DUR
      GO TO 622
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  612 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
```

```
C.....CALCULATES POINT OF MINIMUM EFFECTIVE PRESSURE.....
      DIV=(DUR-TS)/50.
      DO 613 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 614,614,613
  613 CONTINUE
  614 CALF=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-.1)*(TEND-TS)+(TEND-TS)*PEND
C.....BLAST LOADING ON REAR OF BUS
      TA=((7.2+42.)/VEL)*1000.
      TIME=TA-(7.2/VEL)*1000.
      PTA=PI*(1.-TIME/DUR)*EXP(-TIME/DUR)-.3*QO*(1.-TIME/DUR)**2.
     **EXP(-2.*TIME/DUR)
      IF(TEND-TA)  616,619,619
  616 PTI=PTA*TEND/TIME-7.2*PTA/42.
      CALB=.5*PTI*(TEND-(7.2*1000./VEL))
      GO TO 621
  619 CALB=.5*PTA*TIME+.5*PTA*(TEND-TIME)
  621 CALI=CALF-CALB
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  622 IF(CI-CALI) 607,620,620
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  620 WRITE(3,21) CS(L),R
      WRITE(3,17) PI,PR,DUR
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 670,671,671
  671 WRITE(3,50) PI
      GO TO 672
  670 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 673,674,674
  674 WRITE(3,51) PI
      GO TO 672
  673 M=((FV-CV)/50.)
      S=M*.1+.1
      WRITE(3,52) S,PI
  672 GO TO 606
  607 CONTINUE
  606 CONTINUE
  605 CONTINUE
      CALL LINK(CALLR)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   18 FORMAT(1X,'CRITICAL IMPULSE FOR BUS OVERTURNING',//)
   19 FORMAT(1X,'BUS WEIGHT',10X,'C GRAVITY',10X,'C IMPULSE',)
   25 FORMAT(1X,'LBS',10X,'INCHES',10X,'PSI-MSEC',//)
   20 FORMAT(3F10.2)
   21 FORMAT(1X,'CHARGE WEIGHT=',F10.2,10X,'DISTANCE=',F10.2,/)
   24 FORMAT(1X,'MINIMUM DISTANCE FOR WEIGHT=',F10.2,10X,'CG=',F10.2, )
   50 FORMAT(1X,'INSUFFICIENT DATA CONCERNING PLATE GLASS FRAGMENTS',
     *1X,'AT PI=',F10.2,/)
   51 FORMAT(1X,'USING WINDOW G. DATA,PROB. OF SERIOUS WOUNDS IS 0.',
     *1X,'AT PI=',F10.2,/)
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```
   52 FORMAT(1X,'USING W. G. DATA,PROB. OF SER. WOUNDS=',F10.2,
     *1X,'AT PI=',F10.2,/)
   53 FORMAT(1X,'PRO+A+ILITY OF GLASS FRAGMENT INJURY', )
      END
// DUP
*STORE      WS  UA  BUS
// JOB
// DUP
*DELETE             CAMPR
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON      PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C..............................................
C     CAMPER OVERTURN SUBROUTINE
C..............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      BASE=33.
      III=1
C.....DETERMINES NO. OF PARAMETERS FOR CAMPER.....
      DO 700 I=1,4
      IF( CCG(I)) 701,701,700
  701 K1=I-1
      GO TO 702
  700 CONTINUE
      K1=4
C..............................................
C.....CRITICAL IMPULSE FOR CAMPER AND TRUCK UNIT.....
C..............................................
  702 DO 703 I=1,K1
      CGT=CTG(I)
      CGC=CCG(I)
      DO 703 II=1,K1
      WTR=TRW(II)
      WCP=CPW(II)
      DIST1=SQRT(CGT**2.+BASE**2.)
      DIST2=SQRT(CGC**2.+BASE**2.)
      RISE1=DIST1-CGT
      RISE2=DIST2-CGC
      WORK=WTR*RISE1+WCP*RISE2
      AI=((WTR+WCP)/386.)*((72.**2.+54.**2.)/ 12.+2612.)
      AIA=.5*AI
      OMGA=WORK/AIA
      OMGA=SQRT(OMGA)
      PULSE= AI*OMGA/60.
  703 UI(I,II,III)=PULSE*1000./17640.
      WRITE(3,20)
      WRITE(3,22)
      WRITE(3,25)
```

```
      DO 704 I=1,K1
      DO 704 J=1,K1
  704 WRITE(3,11) CPW(I),TRW(I),CCG(J),CTG(J),UI(I,J,III)
C..................................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C..................................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 705 I=1,K1
      CGT=CTG(I)
      CGC=CCG(I)
      DO 705 J=1,K1
      WTR=TRW(J)
      WCP=CPW(J)
      WRITE(3,23) WCP,WTR,CGC,CGT
C.....VARIATION OF CHARGE SIZE.....
      DO 706 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 707 L1=1,50
      CI=UI(I,J,III)
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 708,708,709
  708 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 710
  709 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  710 QQ=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.-(6.*PI)/(102.9+PI))
      TS=(3.*7.5/VEL)*1000.
      IF(DUR-TS)711,712,712
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  711 CALI=.5*PR*DUR
      GO TO 722
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  712 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QQ*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
      DIV=(DUR-TS)/50.
      DO 713 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QQ*(1.-TEND/DUR)**2.*EXP(-2.*
     *TEND/DUR)
      IF(PEND-.2) 714,714,713
  713 CONTINUE
  714 CALF=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-.1)*(TEND-TS)+PEND*(TEND-TS)
C.....BLAST LOADING ON REAR SIDE OF CAMPER AND TRUCK UNIT.....
      TA=((9.+42.)/VEL)*1000.
      TIME=TA-(9./VEL)*1000.
      PTA=PI*(1.-TIME/DUR)*EXP(-TIME/DUR)-.3*QQ*(1.-TIME/DUR)**2.
     **EXP(-2.*TIME/DUR)
      IF(TEND-TA) 716,719,719
  716 PTI=PTA*TEND/TIME-9.*PTA/42.
      CALB=.5*PTI*(TEND-(9.*1000./VEL))
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      GO TO 721
  719 CALB=.5*PTA*TIME+.5*PTA*(TEND-TIME)
  721 CALI=CALF-CALB
  722 IF(CI-CALI) 707,720,720
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  720 WRITE(3,21) CS(L),R
      WRITE(3,17) PI,PR,DUR
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 770,771,771
  771 WRITE(3,50) PI
      GO TO 772
  770 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 773,774,774
  774 WRITE(3,51) PI
      GO TO 772
  773 M=((FV-CV)/50.)
      S=M*.1+.1
      WRITE(3,52) S,PI
  772 GO TO 706
  707 CONTINUE
  706 CONTINUE
  705 CONTINUE
      CALL LINK(CALLR)
   11 FORMAT(5F10.2)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   20 FORMAT(1X,'CRITICAL IMPULSE FOR CAMPER OVERTURNING',//)
   21 FORMAT(1X,'CHARGE WEIGHT=',F9.0 ,10X,'DISTANCE=',F10.2,/)
   22 FORMAT(1X,'C WGT', 8X,'T WGT',8X, 'C CG',8X,'T CG',8X,'C IMPULSE',
     *)
   23 FORMAT(1X,'MIN DIST FOR C WGT=',F8.2,'T WGT=',F8.2,'C CG=',F8.2,
     *1X,'T CG=',F8.2,/)
   25 FORMAT(1X,'LBS',8X,'LBS',8X,'INCHES',8X,'INCHES',8X,'PSI-MS',/)
   50 FORMAT(1X,'INSUFFICIENT DATA CONCERNING PLATE GLASS FRAGMENTS',
     *1X,'AT PI=',F10.2,/)
   51 FORMAT(1X,'USING WINDOW G. DATA,PROB. OF SERIOUS WOUNDS IS 0.',
     *1X,'AT PI=',F10.2,/)
   52 FORMAT(1X,'USING W. G. DATA,PROB. OF SER. WOUNDS=',F10.2,
     *1X,'AT PI=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURY', )
      END
// DUP
*STORE      WS  UA  CAMPR
// JOB
// DUP
*DELETE             TRLER
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON     PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
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     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRF(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C...............................................
C     HOUSE TRAILER SUBROUTINE
C...............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      BASE=44.
      III=1
C.....DETERMINES NO. OF MOBILE HOME PARAMETERS.....
      DO 800 I=1,4
      IF(TRCG(I)) 801,801,800
  801 K1=I-1
      GO TO 802
  800 CONTINUE
      K1=4
C...............................................
C.....CRITICAL IMPULSE FOR MOBILE HOME
C...............................................
  802 DO 803 I=1,K1
      CG=TRCG(I)
      DO 803 II=1,K1
      W=TRWT(II)
      DIST=SQRT(BASE**2.+CG**2.)
      RISE=DIST-CG
      WORK=RISE*W
      AI=(W/386.)*((120.**2.+108.**2.)/ 12.+7125.)
      AIA=.5*AI
      OMGA=WORK/AIA
      OMGA=SQRT(OMGA)
      PULSE=AI*OMGA/84.
  803 UI(I,II,III)=PULSE*1000./61200.
      WRITE(3,24)
      WRITE(3,25)
      WRITE(3,26)
      DO 804 I=1,K1
      DO 804 J=1,K1
      CG=TRCG(I)
      W=TRWT(J)
      CI=UI(I,J,III)
  804 WRITE(3,11) CG,W,CI
C...............................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C...............................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 805 I=1,K1
      CG=TRCG(I)
      DO 805 J=1,K1
      W=TRWT(J)
      WRITE(3,29)W,CG
C.....VARIATION OF CHARGE SIZE.....
      DO 806 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 807 L1=1,50
      CI=UI(I,J,III)
```

```
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 808,808,809
  808 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 810
  809 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  810 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.-(6.*PI)/(102.9+PI))
      TS=(3.*10./VEL)*1000.
      IF(DUR-TS) 811,812,812
  811 CALI=.5*PR*DUR
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
      GO TO 822
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  812 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
C.....CALCULATES POINT OF MINIMUM EFFECTIVE PRESSURE.....
      DIV=(DUR-TS)/50.
      DO 813 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 814,814,813
  813 CONTINUE
  814 CALF=.5*(PR-PTS)*TS+TS*PTS+.5*(PTS-PEND)*(TEND-TS)+(TEND-TS)*PEND
C.....BLAST LOADING ON REAR OF MOBILE HOME
      TA=((10.+40.)/VEL)*1000.
      TIME=TA-(10./VEL)*1000.
      PTA=PI*(1.-TIME/DUR)*EXP(-TIME/DUR)-.3*QO*(1.-TIME/DUR)**2.
     **EXP(-2.*TIME/DUR)
      IF(TEND-TA) 816,819,819
  816 PTI=PTA*TEND/TIME-10.*PTA/40.
      CALB=.5*PTI*(TEND-(10.*1000./VEL))
      GO TO 821
  819 CALB=.5*PTA*TIME+.5*PTA*(TEND-TIME)
  821 CALI=CALF-CALB
  822 IF(CI-CALI) 807,820,820
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  820 WRITE(3,21) CS(L),R
      WRITE(3,17) PI,PR,DUR
C.....GLASS FRAGMENT INJURY MODEL.....
      WRITE(3,53)
      IF(PI-5.) 870,871,871
  871 WRITE(3,50) PI
      GO TO 872
  870 FW=-.75*PI+3.9
      FV=18.7*PI+62.5
      CV=230.*EXP(-1.9*FW)+103.
      IF(CV-FV) 873,874,874
  874 WRITE(3,51) PI
      GO TO 872
  873 M=((FV-CV)/50.)
```

```
      S=M*.1+.1
      WRITE(3,52) S,PI
  872 GO TO 806
  807 CONTINUE
  806 CONTINUE
  805 CONTINUE
      CALL LINK(CALLR)
   11 FORMAT(3F10.2)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
   21 FORMAT(1X,'CHARGE WEIGHT=',F9.0 ,10X,'DISTANCE=',F10.2,/)
   24 FORMAT(1X,'CRITICAL IMPULSE FOR HOUSE TRAILER',//)
   25 FORMAT(1X,'TRAILER CG',10X,'TRAILER WGT',10X,'C IMPULSE', )
   26 FORMAT(1X,'INCHES',10X,'LBS',10X,'PSI-MS',/)
   29 FORMAT(1X,'MINIMUM DISTANCE FOR WGT=',F10.2,'CG=',F10.2,/)
   50 FORMAT(1X,'INSUFFICIENT DATA CONCERNING PLATE GLASS FRAGMENTS',
     *1X,'AT PI=',F10.2,/)
   51 FORMAT(1X,'USING WINDOW G. DATA,PROB. OF SERIOUS WOUNDS IS 0.',
     *1X,'AT PI=',F10.2,/)
   52 FORMAT(1X,'USING W. G. DATA,PROB. OF SER. WOUNDS=',F10.2,
     *1X,'AT PI=',F10.2,/)
   53 FORMAT(1X,'PROBABILITY OF GLASS FRAGMENT INJURY', )
      END
// DUP
*STORE      WS  UA  TRLER
// JOB
// DUP
*DELETE               DOOR
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON       PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C............................................
C     IGLOO DOOR SUBROUTINE
C............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      FEET=120.
      AI=12.82
C.....DETERMINES NO. OF IGLOO DOOR PARAMETERS.....
      DO 900 I=1,4
      IF(DORS(I)) 901,901,900
  901 K1=I-1
      GO TO 902
  900 CONTINUE
      K1=4
C............................................
C.....CRITICAL IMPULSE FOR IGLOO DOOR.....
C............................................
      II=1
```

```
      III=1
  902 DO 903 J=1,K1
      SIG=DORS(J)*10000.
      BEND=SIG*AI/2.71
      WORK=BEND*.3075
      S=1.1
      H=SQRT(2.*1.1*WORK)
  903 UI(J,II,III)=H*1000./2880.
      WRITE(3,29)
   29 FORMAT(1X,'CRITICAL IMPULSE FOR IGLOO DOOR',/)
      WRITE(3,30)
      WRITE(3,40)
      DO 904 J=1,K1
      SIG=DORS(J)*10000.
  904 WRITE(3,11) SIG,UI(J,II,III)
C.................................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C.................................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 905 I=1,K1
      CI=UI(I,II,III)
      SIG=DORS(I)*10000.
C.....VARIATION OF CHARGE SIZE.....
      WRITE(3,31) SIG
      DO 906 L=1,5
C.....VARIATION OF SCALED DISTANCE.....
      DO 907 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 917,917,918
  917 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 919
  918 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
  919 QO=2.5*(PI**2.)/(102.9+PI)
      VEL=1187.*SQRT(1.+(6.*PI)/(102.9+PI))
      TS=(3.*10./VEL)*1000.
      IF(DUR-TS)920,920,921
C.....CASE I. DURATION OF BLAST LESS THAN TIME TO STAG.
  920 CALI=.5*PR*DUR
      GO TO 922
C.....CASE II.TIME TO STAG. LESS THAN DURATION
  921 PTS=PI*(1.-TS/DUR)*EXP(-TS/DUR)+QO*(1.-TS/DUR)**2.*EXP(-2.
     **TS/DUR)
      DIV=(DUR-TS)/50.
      DO 1140 I7=1,50
      S=I7
      TEND=TS+S*DIV
      PEND=PI*(1.-TEND/DUR)*EXP(-TEND/DUR)+QO*(1.-TEND/DUR)**2.*EXP(-2.
     **TEND/DUR)
      IF(PEND-.2) 1141,1141,1140
 1140 CONTINUE
 1141 CALI=.5*(PR-PTS)*TS+TS*PTS+.5*PTS*(TEND-TS)
```

```
  922 IF(CI-CALI) 907,924,924
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
  924 WRITE(3,28) CS(L),R
      WRITE(3,17) PI,PR,DUR
      GO TO 906
  907 CONTINUE
  906 CONTINUE
  905 CONTINUE
      CALL LINK(CALLR)
   11 FORMAT(2F15.2)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,//)
   28 FORMAT(1X,'CHARGE WEIGHT=',F9.0 ,'DISTANCE=',F10.2,/)
   31 FORMAT(1X,'MINIMUM DISTANCE FOR STRESS=',F9.0 ,/)
   30 FORMAT(1X,'MODULUS OF RUPTURE',10X,'C IMPULSE', )
   40 FORMAT(1X,'LBS/SQ IN',15X,'PSI-MS',/)
      END
// DUP
*STORE      WS  UA  DOOR
// JOB
// DUP
*DELETE              MAN
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON      PO(50),TAU(50),CPR(50),HRF(4),HRW(4),HRS(4),HFF(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C..............................................
C     MAN TRANSLATION MODEL
C..............................................
C.....FIXED PARAMETER VALUES.....
      A=1./3.
      III=1.
C.....DETERMINES NO. OF MAN TRANSLATION PARAMETERS.....
      DO 1000 I=1,4
      IF(WMAN(I)) 1001,1001,1000
 1001 K1=I-1
      GO TO 1002
 1000 CONTINUE
      K1=4
C..............................................
C.....CRITICAL IMPULSE FOR MAN TRANSLATION.....
C..............................................
 1002 DO 1003 I=1,K1
      W=WMAN(I)
      DO 1003 J=1,K1
      PA=PMAN(J)
 1003 UI(I,J,III)=(72000.*W/386.)/(PA*144.)
      WRITE(3,30)
      WRITE(3,31)
      WRITE(3,40)
```

```
      DO 1004 I=1,K1
      DO 1004 J=1,K1
      W=WMAN(I)
      PA=PMAN(J)
 1004 WRITE(3,32) W,PA,UI(I,J,III)
C.................................................
C.....DETERMINES MINIMUM STAND-OFF STORAGE DISTANCE FOR EACH
C.....CHARGE SIZE AND SET OF PARAMETER VALUES.....
C.................................................
C.....VARIATION OF PARAMETER VALUES.....
      DO 1005 I=1,K1
      DO 1005 J=1,K1
      CI=UI(I,J,III)
      W=WMAN(I)
      PA=PMAN(J)
      WRITE(3,33) W,PA
C.....VARIATION OF CHARGE SIZE.....
      DO 1006 L=1,5
      SO=0.
C.....VARIATION OF SCALED DISTANCE.....
      DO 1007 L1=1,50
C.....BLAST PARAMETERS FOR   SCALED DISTANCE
      PI=PO(L1)
      DUR=TAU(L1)*CS(L)**A
      IF(L1-37) 1008,1008,1009
 1008 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 1010
 1009 S=L1
      R=((S-37)*5.+40.)*CS(L)**A
 1010 QO=2.5*(PI**2.)/(102.9+PI)
      PR=2.*PI*(102.9+4.*PI)/(102.9+PI)
C.....EAR DRUM RUPTURE IS INCURRED IF REFLECTED PRESSURE IS
C.....GREATER THAN 5. PSI.....
      IF(PR-5.) 1011,1012,1012
 1012 RANGE=R
      GO TO 1007
 1011 S=QO*DUR*.5
      IF(S-CI) 1013,1013,1014
 1014 SO=R
      GO TO 1007
 1013 IF(SO) 1015,1015,1016
C.....MINIMUM DISTANCE FOR GIVEN CHARGE SELECTED.....
 1015 WRITE(3,34) CS(L),RANGE
      GO TO 1006
C.....MAXIMUM TRANSLATION DISTANCE.....
 1016 DIST=.7*3.5*DUR/1000.
C.....MAXIMUM ACCELERATION.....
      ACC=QO*PA/(W/386.)
      WRITE(3,36) CS(L),RANGE
      WRITE(3,35) SO,DIST,ACC
      GO TO 1006
 1007 CONTINUE
 1006 CONTINUE
 1005 CONTINUE
      CALL LINK(CALLR)
   30 FORMAT(1X,'CRITICAL IMPULSE FOR MAN'/)
```

```
   31 FORMAT(1X,'MAN WEIGHT=',10X,'MAN P AREA=',10X,'C IMPULSE=', )
   40 FORMAT(1X,'LBS',15X,'SQ IN',15X,'PSI-MS',/)
   32 FORMAT(3F10.2)
   33 FORMAT(1X,'MINIMUM DISTANCE FOR MAN WGT=',F10.2,10X,'P AREA=',
     *F10.2,/)
   34 FORMAT(1X,'FOR C SIZE=',F9.0 ,'ONLY EAR DAMAGE AT R=',F10.2,'IS',
     *'INCURRED',/)
   35 FORMAT( 5X,'TRANSLATION AT R=',F10.2,1X,'T DIST=',F10.2,'ACC=',
     *F10.2,/)
   36 FORMAT(1X,'FOR C SIZE=',F9.0 ,'EAR DAMAGE AT',F10.2,)
      END
// DUP
*STORE      WS  UA  MAN
// JOB
// DUP
*DELETE             AIRP
// FOR
*ONE WORD INTEGERS
*ARITHMETIC TRACE
*TRANSFER TRACE
*IOCS(CARD,1132 PRINTER)
      COMMON      PO(50),TAU(50),CPR(50),HRE(4),HRW(4),HRS(4),HFE(4),
     *HFW(4),HFS(4),HBE(4),HBT(4),CRE(4),CRW(4),CRS(4),CDE(4),CDW(4),
     *CDS(4),SBWE(4),SBT(4),SRE(4),SRW(4),SRS(4),OHE(4),OHT(4),OFE(4),
     *CTG(4),TRW(4),CPW(4),TRCG(4),TRWT(4),DORS(4),WMAN(4),PMAN(4),
     *OFT(4),IA(11),K,NOT,UI(4,4,4),TC(4,4,4),CS(5),BCG(4),BW(4),CCG(4),
     *AIRE(4),AIRF(10),TC2(4,4,4),TC3(4,4,4),UI2(4,4,4),UI3(4,4,4)
C     AIRCRAFT SUBROUTINE
      A=1./3.
      A2=.3044
      AI=.3079
      G=386.
      DO 1100 I=1,4
      IF(AIRE(I)) 1101,1101,1100
 1101 K1=I-1
      GO TO 1102
 1100 CONTINUE
      K1=4
 1102 WRITE(3,12)
      WRITE(3,13)
      WRITE(3,40)
      DO 1103 I=1,K1
      E=AIRE(I)*1000000.
      P=36.+(I-1)*2.13
 1103 WRITE(3,14) E,P
      DO 1104 I=1,K1
      E=AIRE(I)*1000000.
      DO 1105 L=1,5
      DO 1106 L1=1,50
      IF(L1-37) 1111,1111,1112
 1111 S=L1
      R=(S+3.)*CS(L)**A
      GO TO 1113
 1112 S=L1
      R=((S-37.)*5.+40.)*CS(L)**A
 1113 PI=PO(L1)
      DUR=TAU(L1)*CS(L)**A
```

```
      P=36.+(I-1)*2.13
      F=DUR/P
      IF(F-.5) 1114,1114,1115
 1114 FAC=1.
      GO TO 1109
 1115 IF(F-5.) 1107,1108,1108
 1108 FAC=1.81
      GO TO 1109
 1107 S=F/.5
      M=S
      DIF=S-M
      FAC=AIRF(M)+DIF*(AIRF(M+1)-AIRF(M))
 1109 PRES=7.23/FAC
      IF(PRES-CPR(L1)) 1106,1110,1110
 1110 WRITE(3,18) CS(L),R
   18 FORMAT(1X,'CHARGE WGT=',F10.2,10X,'DISTANCE=',F10.2,)
      WRITE(3,17) PI,CPR(L1),DUR
      GO TO 1105
 1106 CONTINUE
 1105 CONTINUE
 1104 CONTINUE
      CALL LINK(CALLR)
   12 FORMAT(1X,'FULL NATURAL PERIOD OF FRAME MEMBER',/)
   13 FORMAT(1X,'E',15X,'FULL PERIODS(MS)',)
   40 FORMAT(1X,'LBS/SQ IN',15X,'MSEC',/)
   14 FORMAT(F10.0,F8.0)
   17 FORMAT(5X,'INC. OVPRES.=',F10.2,'PEAK REFL.PRES.=',F10.2,
     *'DUR.=',F10.2,/)
      END
// DUP
*STORE      WS  UA  AIRP
```

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13. ABSTRACT

Computer programmed methodology has been formulated which may be used to estimate minimum separation distances for the storage of five different quantities of stored explosives with respect to minimizing damage to ten specific types of civilian targets. These procedures have been based on the results of more recent analytical and experimental blast damage assessment programs in which structures or structural elements subject to blast could be related to the civilian targets of interest through similar structural elements and construction techniques.

Analytical techniques have been programmed which will develop a minimum separation distance, for a selected target and quantity of explosives, which minimizes the probable risk that the blast damage resulting from an accidental detonation will exceed a predetermined acceptable level. A discussion of the program and operating instructions are presented in this manual.

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